

Oasis montaj Tutorial

for

Gravity and Magnetic Exploration
Principles, Practices, and Applications

(W.J. Hinze, R.R.B. von Frese, and A.H. Saad; 2013,
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1. Introduction

The sections below describe the magnetic and gravity data processing operations of *Oasis montaj* that are utilized for the Geosoft-based exercises. This is a generic tutorial for *Oasis montaj* but the examples used are taken from an exercise dealing with magnetic and gravity anomaly data of Minnesota.

Contextual notes are preceded with 🍌. You can view help topics for any *Oasis montaj* window or dialog box by clicking the help button ? in the top-right corner.

2. Magnetic Data Processing

This section illustrates the magnetic anomaly mapping, processing, and filtering operations of *Oasis montaj* using the total field data from the northeastern Minnesota study area 'A' shown in the micro-leveled aeromagnetic survey data of *Figure 1*.

The magnetic anomaly data were primarily observed under the auspices of the Minnesota Geological Survey along north/south flight paths separated by 400 m at a mean terrain clearance of 150 m (Chandler, 1985, 1991, 1996; Chandler et al., 2007).

The total magnetic intensity measurements were made with a proton precession magnetometer mounted in a tail-stinger at an interval of either 50 or 75 m, leveled with tie-line observations measured at either 2 or 4 km intervals, and processed for anomaly values using standard methodologies. Subsequently the magnetic data were micro-leveled using Geosoft's *Oasis montaj* software.

Start a new project

1. In Windows explorer, create a folder under the GM root folder and name it *Minnesota*.
2. If you have not already done so, download the exercise data *Minnesota_Data.zip*. Unzip it in the *Minnesota* folder.
3. Open *Oasis montaj*.
4. From the **File** menu, click **Project**, then click **New**. Name the project *Minnesota*. Save this project file in the *Minnesota* folder.

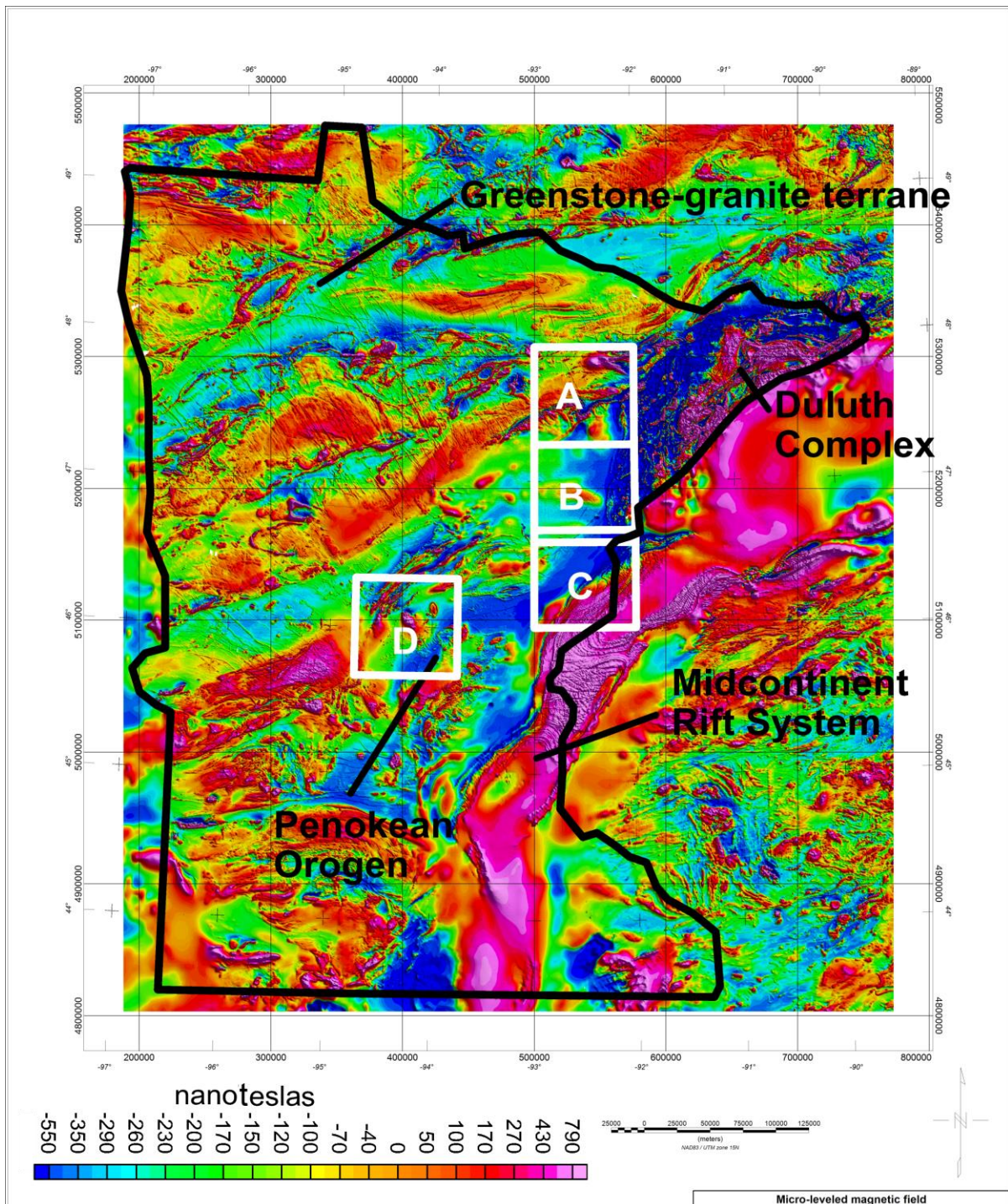


Figure 1: Micro-leveled residual field aeromagnetic survey anomalies of Minnesota with the study areas outlined that are considered in the Geosoft-based exercises. The geomagnetic north is to the top of the map.




Import magnetic data

Start by importing the magnetic survey data into an *Oasis montaj* database. Before importing the data into a database, however, use an editor and inspect the file *MN_mag A.XYZ*. This is an ASCII file containing a header followed by segments of data. The header is not mandatory but defines the data field names. Each data segment starts with a line label followed by a numeric data value in a constant number of fields. Now you can proceed with the import:

1. On the **Database** menu, click **Import**, then click **Geosoft XYZ**.
2. You will be prompted to provide a database name. Name it *MN_Mag_A*
3. As we will be processing the data and producing more lines and channels, increase the number of lines to 500 and channels to 32. Click **OK**. This will open the new database in the *Minnesota* workspace. Note that the database is not yet committed to disk.

You will now proceed to import the Minnesota magnetic data provided for the study area A-exercise into this newly created database.

- 4.
5. For the XYZ data file, browse for *MN_mag_A.XYZ*.
6. Since the fields to import are not yet defined, click the **Template** button located at the bottom-right of the dialog window. Since the header contains the field name, the next dialog will be accordingly populated.
7. Highlight each field and select the proper format from the **Format** dropdown list located in the **Source data** group.
8. Verify that the fields are properly defined in the **Output** group.
9. You can ignore the other entries for now as the import tool will select appropriate defaults.
10. Click **OK** and then click **OK** again to trigger the data import.

-  The time and geographic fields are of type *double* and saved as such in the database. For easier readability however they are displayed as column separated values.
-  Channel names are not case sensitive and must not contain blanks or the characters [*\t,-,&,%,\$,;,,"',]*.
-  By default the auto-save is turned on and you will be periodically prompted to commit the changes to disk.

Import ..\Minnesota_Data\Minnesota_Data\MN_Mag_A.XYZ

Template Name: e:\projects\book\minnesota\exercises\pmtutorial\default.i0

Field #	Example	Output Channel
1	04:12:27.0	Time
2	47.15.05.35	Latitude
3	-92.17.23.42	Longitude
4	1804.14	AltBaro
5	572.73	AltRadar
6	59614.90	TotalMag
7	-523.89	ResidMag
8	0.50	VertDer

Source Data:

Field #: 8
 Array Size: 1
 Example: 0.50
 Format: Normal
 Dummy:

Output:

Name: VertDer
 Type: Double
 Dec.: 2
 Width: 10
 Unit:

OK Cancel Help

Figure 2: Data import template.

By default the template will be saved in your working folder under the name *default.i0* as indicated in *Figure 2: Template Name* located at the top of the illustration. If you attempt to import data of the same format in this or another database, you can directly enter the name of the template and bypass entering the channel names again.

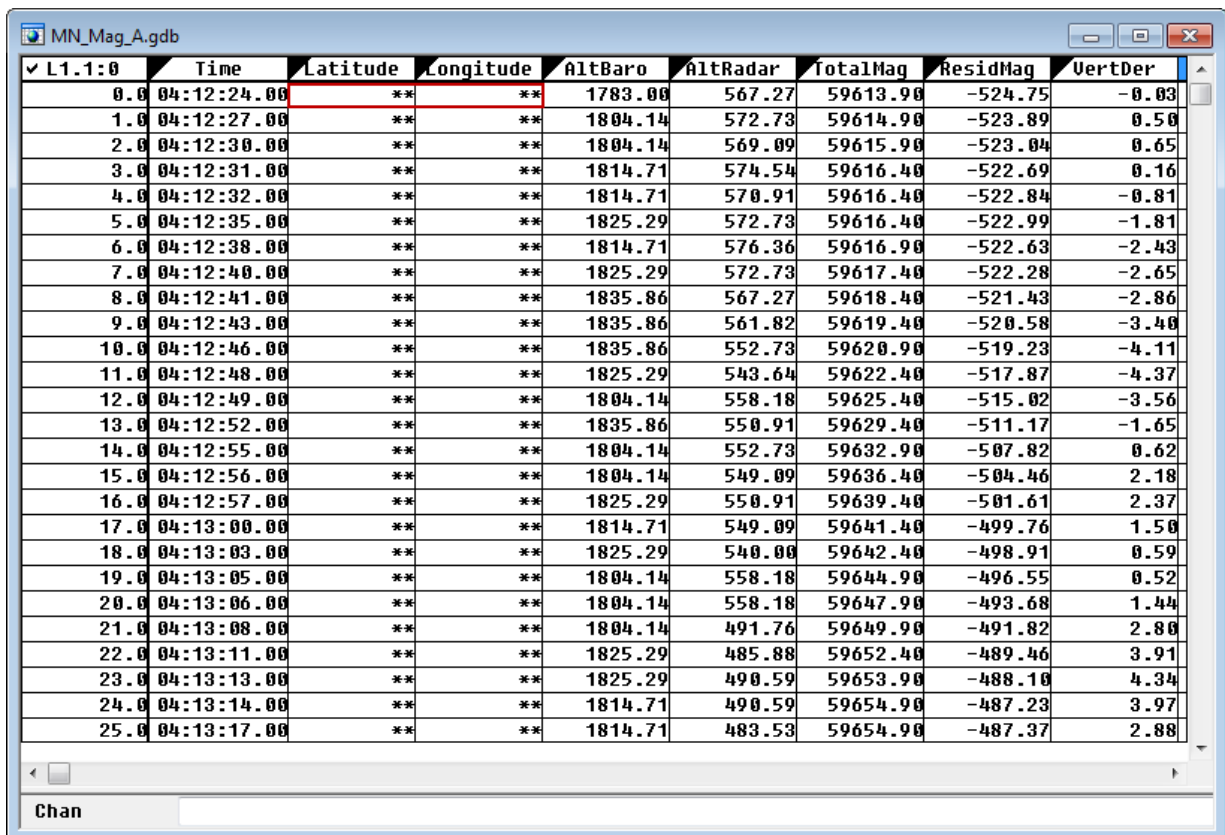
All the fields that are imported into database channels are initially protected to maintain the integrity of the original data. It is strongly recommended not to alter these database channels. You can, however, make copies of these channels to work on. When a channel is protected, a black triangle appears in the upper left corner of the label indicating that it cannot be modified. To unprotect a channel, you can right-click on the label of the channel and toggle the protection off, or select **Protect None** to free all of the channels.

Upon import both Time and Latitude/Longitudes are interpreted properly, but stored as double precision float values. To display these as degrees/minute/seconds:

1. Right-click on the *Longitude* column header and
2. Click **Edit** from the drop down menu. In the **Display** group, drop down the **Format** list and select *Geographic*.

Any occurrence of ** in a database cell [e.g., *Figure 3*] indicates that not all of the digits of the newly formatted field can be displayed in the cell. To mitigate it, widen the columns by clicking and dragging on the right side of a cell until the numbers appear.

3. Repeat this process for *Latitude*.
4. Repeat this process for *Time* and select the appropriate format.



L1.1:0	Time	Latitude	Longitude	AltBaro	AltRadar	TotalMag	ResidMag	VertDer
0.0	04:12:24.00	**	**	1783.00	567.27	59613.90	-524.75	-0.03
1.0	04:12:27.00	**	**	1804.14	572.73	59614.90	-523.89	0.50
2.0	04:12:30.00	**	**	1804.14	569.09	59615.90	-523.04	0.65
3.0	04:12:31.00	**	**	1814.71	574.54	59616.40	-522.69	0.16
4.0	04:12:32.00	**	**	1814.71	570.91	59616.40	-522.84	-0.81
5.0	04:12:35.00	**	**	1825.29	572.73	59616.40	-522.99	-1.81
6.0	04:12:38.00	**	**	1814.71	576.36	59616.90	-522.63	-2.43
7.0	04:12:40.00	**	**	1825.29	572.73	59617.40	-522.28	-2.65
8.0	04:12:41.00	**	**	1835.86	567.27	59618.40	-521.43	-2.86
9.0	04:12:43.00	**	**	1835.86	561.82	59619.40	-520.58	-3.40
10.0	04:12:46.00	**	**	1835.86	552.73	59620.90	-519.23	-4.11
11.0	04:12:48.00	**	**	1825.29	543.64	59622.40	-517.87	-4.37
12.0	04:12:49.00	**	**	1804.14	558.18	59625.40	-515.02	-3.56
13.0	04:12:52.00	**	**	1835.86	550.91	59629.40	-511.17	-1.65
14.0	04:12:55.00	**	**	1804.14	552.73	59632.90	-507.82	0.62
15.0	04:12:56.00	**	**	1804.14	549.09	59636.40	-504.46	2.18
16.0	04:12:57.00	**	**	1825.29	550.91	59639.40	-501.61	2.37
17.0	04:13:00.00	**	**	1814.71	549.09	59641.40	-499.76	1.50
18.0	04:13:03.00	**	**	1825.29	540.00	59642.40	-498.91	0.59
19.0	04:13:05.00	**	**	1804.14	558.18	59644.90	-496.55	0.52
20.0	04:13:06.00	**	**	1804.14	558.18	59647.90	-493.68	1.44
21.0	04:13:08.00	**	**	1804.14	491.76	59649.90	-491.82	2.80
22.0	04:13:11.00	**	**	1825.29	485.88	59652.40	-489.46	3.91
23.0	04:13:13.00	**	**	1825.29	490.59	59653.90	-488.10	4.34
24.0	04:13:14.00	**	**	1814.71	490.59	59654.90	-487.23	3.97
25.0	04:13:17.00	**	**	1814.71	483.53	59654.90	-487.37	2.88

Figure 3: Imported magnetic data where the properly formatted fields record numeric values [e.g., time] and the occurrence of ** marks fields with too few columns to accommodate the available numeric values.

Define Coordinate Projection

To set the projection and transform the coordinates into a Universal Transverse Mercator [UTM] projection (see *Hinze et al. (2013), Appendix A.6.1*):

1. On the **Coordinates** menu, click **New Projected Coordinate System**.

2. Set **Current X/Longitude Channel**: *LONGITUDE* [if not automatically selected, select from drop-down menu]
3. Set **Current Y/Latitude Channel**: *LATITUDE*
4. Set **Process**: *All Lines/Groups*

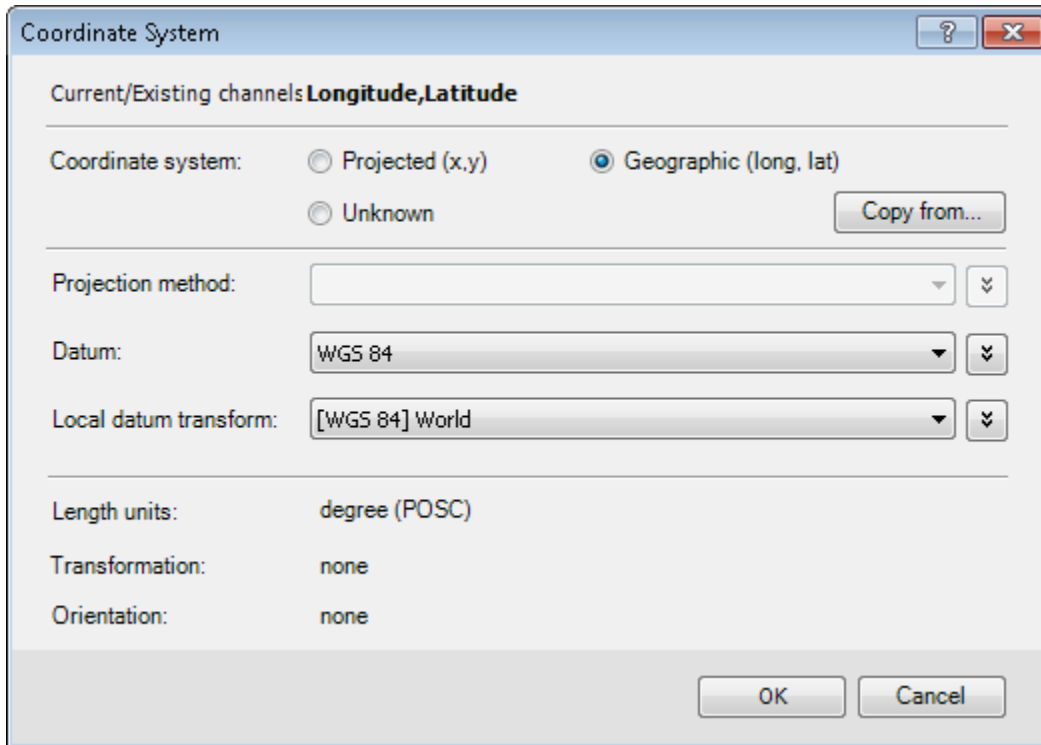


Figure 4: Set geographic coordinates.

5. Click **Next**. Select **Coordinate system**: *Geographic (long, lat)*
6. Set **Datum**: *WGS 84*
7. Set **Local datum transform**: *[WGS 84] World*
8. Click **OK**. *Figure 4* shows the template for setting the geographic coordinate system and *Figure 5* shows the new projected coordinate projection parameters.

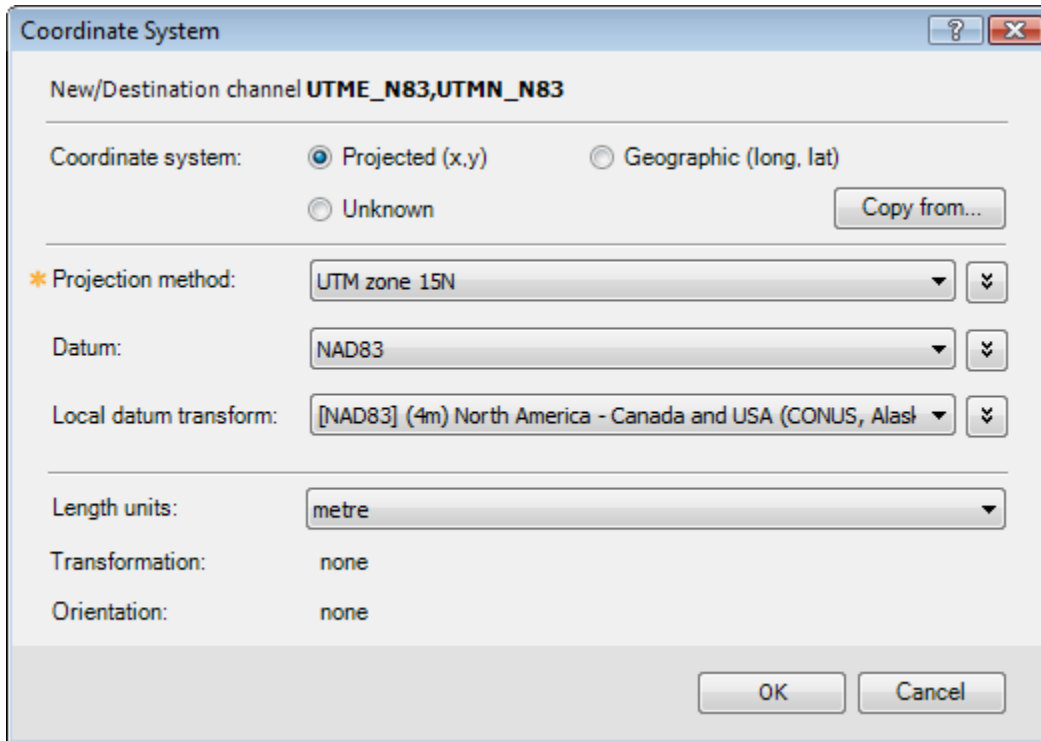



Figure 5: Set projected coordinate system.


9. Set **New X/Longitude Channel**: *UTME_N83*
10. Set **New Y/Latitude Channel**: *UTMN_N83*
11. Click **Next**.
12. Select the **Toggle Coordinate System**: *Projected (x,y)*
13. Set **Length units**: *metre*
14. Set **Datum**: *NAD83*
15. Set **Local datum transform**: *[NAD83] (4m) North America - Canada and USA (subunits...)*
16. Set **Projection Method**: *UTM zone 15N*
17. Click **OK**.

 To locate an entry in the dropdown list faster first type the first character of the item [U] you are looking for, and the dropdown list will advance to the entries starting with the specified letter.

These operations create new channels for the Northings and Eastings in UTM coordinates.

You must now indicate which channels constitute the coordinate system henceforth [Figure 6].

1. On the **Coordinates** menu, click on **Set Current X,Y,Z Coordinates**.
2. Choose for **Current X & Y** respectively *UTME_N83* and *UTMN_N83*.
3. Leave **Current Z** as *None*.

-  Note that the Geosoft-based exercises call for magnetic field data registered in coordinates referenced to the UTM projection.

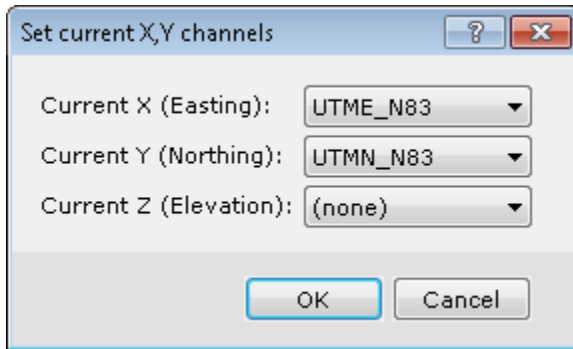




Figure 6: Define coordinates.

-  Every time you update the database it is a good practice to commit the file to disk so that you do not accidentally loose your recent changes. This is achieve with **Database > Save database changes**.

Gridding

The gridded dataset is a very common format for electronic data analysis because data input and storage requirements are minimized and the data are easy to view in a 2D plan map [see Hinze et al. (2013), section 12.4, 12.3, and Appendix A.6.2]. Numerous data gridding options are offered under the **Grid and Image** menu in the *Oasis montaj* workspace. However, before proceeding, let's modify the image viewing attribute from its default value to always display grids as shaded colour image grids [see Hinze et al. (2013), sections 12.4.3, 13.2.3, and A.6.4]. To do so:

1. On the **GX** menu, click **Global settings**, then click **Advanced...**
2. Scroll down to **Image Settings** and
3. Set **Colour Shaded Grids** to *True*.

-  This is a global setting and will be registered on your computer. All subsequent Geosoft project files will obey this setting.

Bi-directional interpolation is commonly applied to grid airborne or ground data that have been collected along mostly parallel lines. This gridding approach interpolates the data at an equal interval, first along and then across the survey lines. If the dataset contains tie lines, they will be ignored. Similarly if lines backtrack, the backtrack segment will be skipped. You will grid the channel *ResidMag*, where the DGRF has been removed and the magnetic intensity anomaly data leveled.

1. On the **Grid and Image** menu, click **Gridding** and then click **Bi-Directional Line Gridding**.
2. Set **Channel to grid**: *ResidMag*
3. Set the name of the **Output grid** file: *MN_bdg_200_A*
4. Set **Grid cell size**: 200

- Click **OK** and the grid will appear on the screen in a new window as illustrated in *Figure 7*.

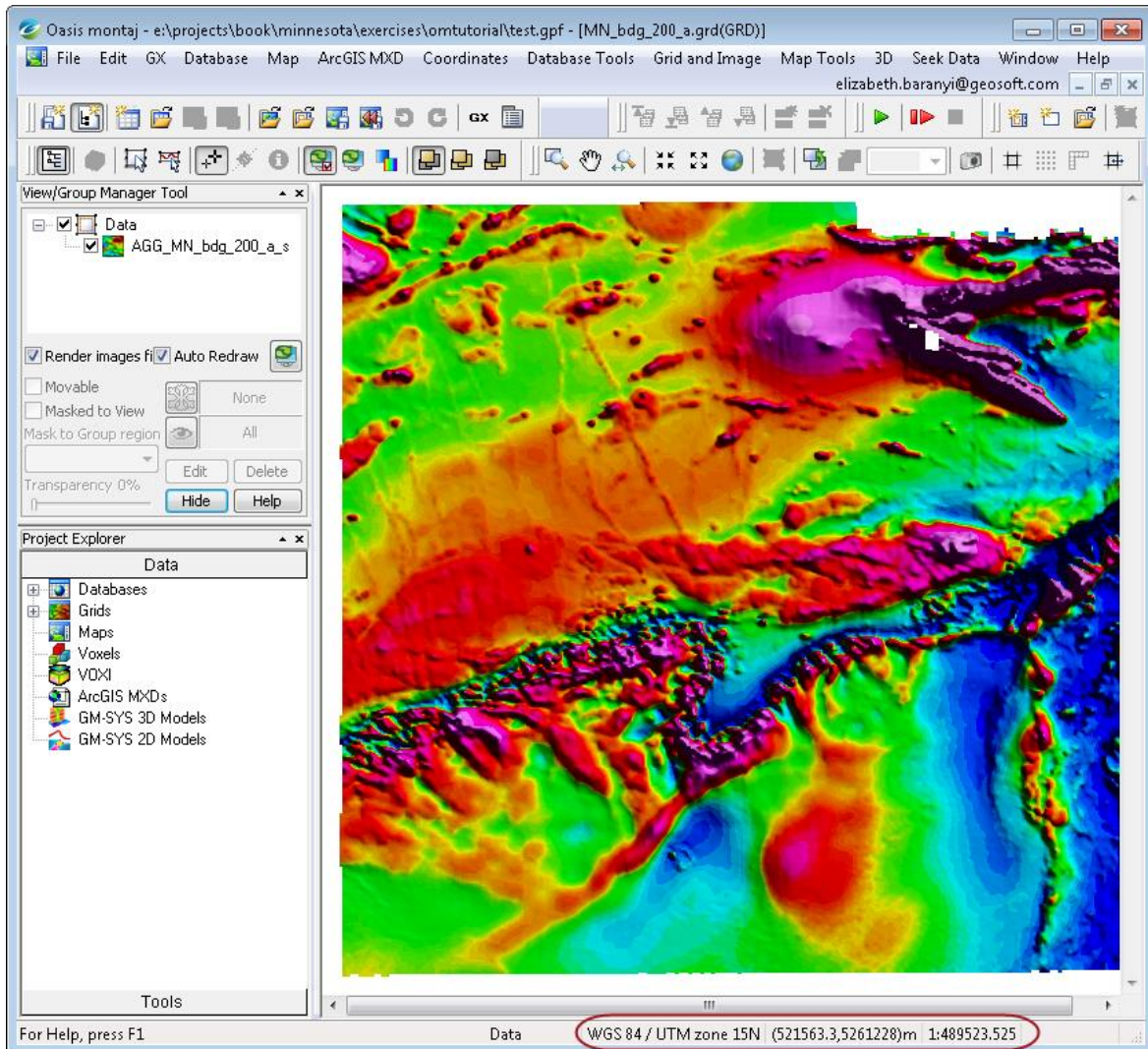


Figure 7: Aeromagnetic anomaly data for study area A of Figure 1. Data are bi-directionally gridded at a 200-m grid interval. Note that the workspace is aware of the projection. This is reported at the right end of the status margin (red oval).

- ✏ The Standard colour distribution for displaying geophysical data is the rainbow colour pallet, named **colour.tbl**, with blue representing the low end of the data values and red the high end of data values.


As a comparison, grid the same anomaly data at a grid interval of 400-m and compare it with the 200-m grid side by side. You will notice that the larger the grid interval the smoother the texture of the gridded data becomes. Effectively increasing the grid cell interval behaves like a smoothing filter. To create the denser grid:

- From the **Grid and Image** menu, click **Gridding** then click **Bi-Directional Line Gridding...**

2. Set **Channel to grid:** *Residmag*
3. Set the name of the **Output grid** file: *MN_bdg_400_A*
4. Set **Grid cell size:** 400
5. Click **OK**. When the gridding is complete, the new grid will load as a colour grid.

Compare the Results

To compare the grids at 200 and 400 m:

1. Load *MN_BDG_200_A.grd* and minimize all the other open objects except for *MN_bdg_400_A.grd*.
2. From the main menu bar select *Window > Tile Vertically* to show the two grids at the same screen resolution and side-by-side.
3. On the shortcut bar click on *Change extents of all maps*  to link and align the view area of both maps
4. The results of the 400 m gridding is on the left of *Figure 8*. You can notice the finer resolution of the 200m grid on the right.

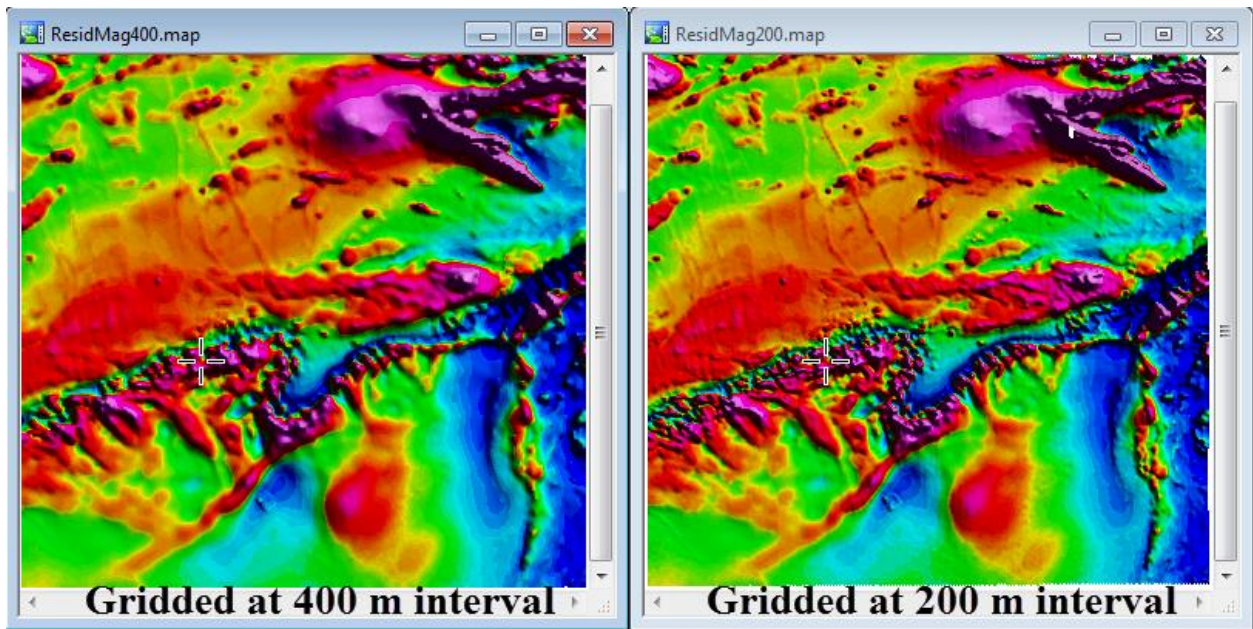



Figure 8: Aeromagnetic anomaly data for study area A [Figure 1] bi-directionally gridded at an interval of 400-m and 200-m.

 The displayed colour anomaly images are not actual maps. They are intended as a verification of the gridding process. You can close and discard them. You will next proceed to create actual maps.

Map Plotting

The grid is the fundamental quantitative basis for making maps and comparing them. To plot a map in *Oasis montaj*, you will start by creating a new empty map to which you add the desired objects to the map. You will begin with plotting a desired base frame, hereafter referred as a basemap.

1. From the **Map Tools** menu, click **New Map** and then click **New Map from X,Y**.
2. The map creation tool suggests logical defaults where possible. It will get the bounding coordinates of the map area from the database.
3. Click **Next**.
4. Set **Map name**: *MN Magnetic Anomaly A*
5. Set **Map template**: *Portrait C*
6. For map scale, Click **Scale** at the bottom of the interface to calculate the smallest scale that will fit in the map. Round up the suggested scale. For study area A, it may be set to 400000.
7. Distance unit is preset to the units specified in the projection, i.e., metre.
8. Click **Finish** and a new empty map will appear on the screen.

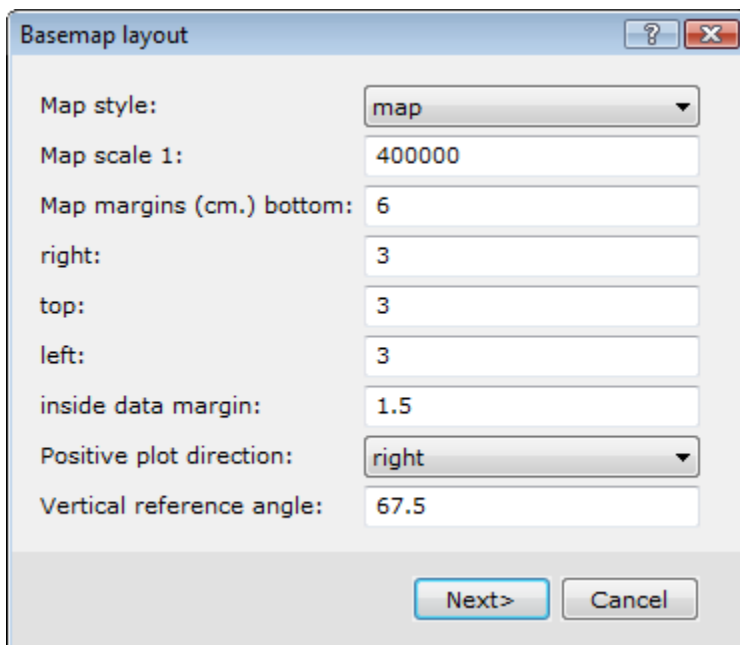


Figure 9: Basemap layout.

To draw in the desired basemap:

1. On the **Map Tools** menu, click the **Base Map**, then click **Draw Base Map**.
2. Only modify the right margin to 3 and accept the remainder defaults for the Basemap layout [Figure 9]. The scale is automatically acquired from the Newmap parameters.
3. Click **Next**.
4. In the **Full map style base map** template [Figure 10] set the following parameters:

- Set **North direction**: 0.0
- Set **Reference grid**: *solid lines*
- Set **Line thickness (microns)**: 150
- Set **Y annotation orientation**: *Vertical, tops out*
- Set **Add compass direction to annotations**: *+X is East*
- Set **Longitude, Latitude annotations?**: *crosses*
- Set **Line thickness (microns)**: 150

5. Click **Next**.

The screenshot shows a dialog box titled "Full map style base map". It contains the following settings:

- North direction (deg. Azimuth from Y): 0.0
- Reference grid: solid lines
- Reference grid spacing: (empty field)
- Line thickness (microns): 150
- Line colour: (black color swatch)
- Y annotation orientation: Vertical, tops out
- Add compass direction to annotations: No
- Longitude, latitude annotations?: crosses
- Longitude increment (deg.mmss): (empty field)
- Latitude increment (deg.mmss): (empty field)
- Line thickness (microns): 150
- Line colour: (black color swatch)

At the bottom, there are three buttons: "<Back", "Next>", and "Cancel". The "Next>" button is highlighted with a blue border.

Figure 10: Full basemap layout.

6. Information about the map can be entered into the Map title block Template [Figure 11]. For example:

- Set **client**: State of Minnesota
- Set **map title**: Magnetic Anomaly Map of Northeast Minnesota
- Set **sub-title**: Area A
- Set **map creator**: Your Name

Map title block

client: State of Minnesota

map title: Magnetic Anomaly Map of North East Minnesota

sub-title: Area A

sub-title:

text line 1:

text line 2:

text line 3:

text line 4:

map creator: Student Name

< Back Finish Cancel

Figure11: Title block template.

- Click **Finish** and the specified map features [North arrow, Scale bar, Title block, Annotated data border, etc.] appear in the main *Oasis montaj* window as illustrated in *Figure 12*.

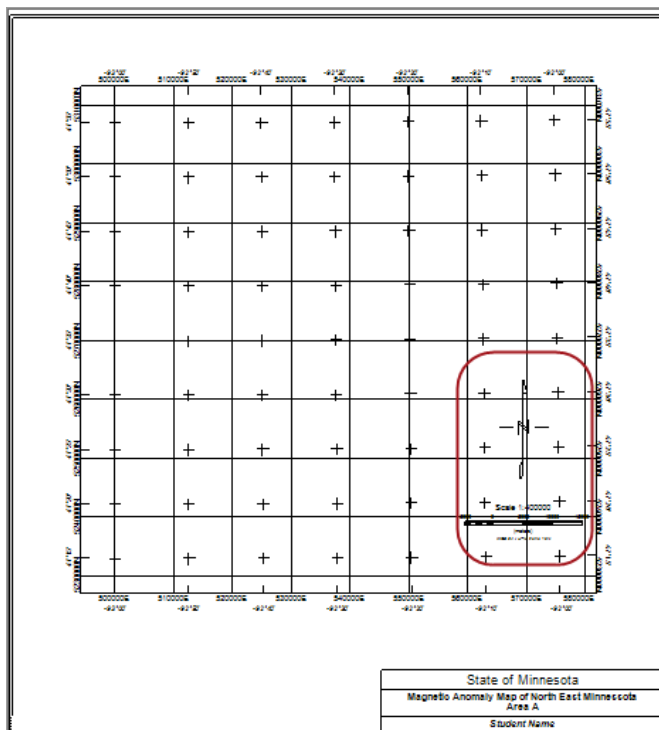


Figure 12: Map containing a title block, scale bar, north arrow, and data area objects (red rectangle).

You will notice that the North arrow and the scale bar are not in a desirable location on the map. This is because we modified the right margin earlier. To locate them approximately as illustrated in *Figure 13*:

1. In the **View/Group Manager Tool** at the top left of the *Oasis montaj* window expand the **Base group** and select **North Arrow**. The North arrow will be highlighted. Now drag and drop it in the bottom margin.
2. Repeat with the Scale bar.

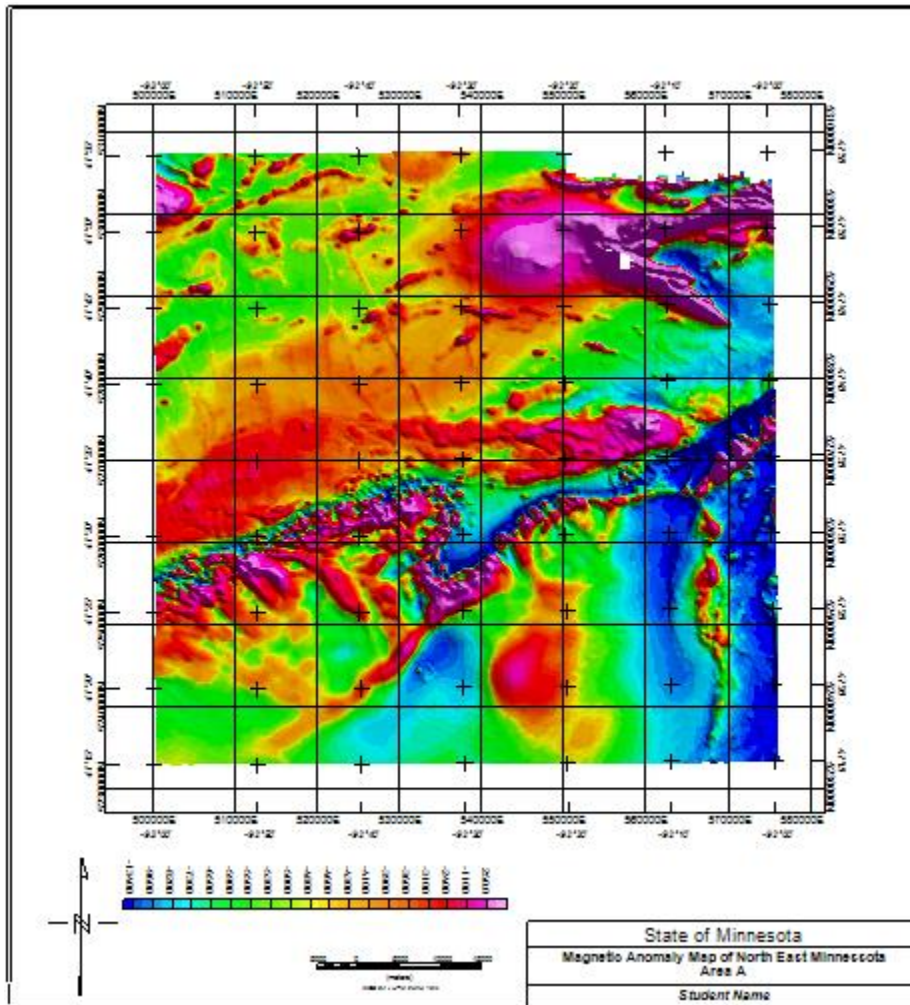



Figure 13: Shaded colour anomaly map. Scale bar and north arrow map objects have been repositioned. Data colour bar is annotated.

- ✎ The scale bar is very handy, but the actual value of the scale (400 000) may be misleading because the illustrations are not plotted to scale in this document. To delete the scale bar, select the Scale bar in the View/Group Manager Tool to highlight it, and then click on the scale value to delete it.
- ✎ In the View/Group Manager Tool you will notice that there are 2 map objects groups, the objects that are in ground coordinate units are grouped

under Data, whereas the legend, north arrow, title block, scale bars and such are grouped under Base.

-  On the contextual right-mouse-button (RMB) menu you will find tools to pan zoom and reset the map. Note the shortcut keys along the right margin of the menu.


To display the data grid with the map parameters:

1. From the **Map Tools** menu, click **Grid and Image**, then **Display** and then **Colour-shaded Grid**. In the dialog enter the following settings:

- Set **Grid name**: *MN_bdg_200_A*
- Set **Colour method**: *Histogram equalization*
- Set **Colour table**: *colour.tbl*
- Set **Contour interval**: *10*


which is approximately 10% of the data standard deviation and will ensure that the colour breaks are at even-numbered values in intervals that are multiples of 10 nT.

2. Click **Current Map** to display the grid on the current map.

-  The top level menus are intended as workflows. You will notice that **Display** can also be accessed through the **Grid and Image** menu, located directly on the menu bar. Since we are working on a map we will access the contextual map tools from the **Map Tools** menu. The outcome of both approaches is the same and only depends on your preference

Shadow Angle

The shadow angle direction can be modified to accentuate desirable high frequency features as shown in *Figure 14*. To do so while a shadow map is open in the *Oasis montaj* workspace:

1. In the *View/Group Manager* tool double click on the colour image *Data\AGG_MN_bdg_200_a* to open the Colour tool.
2. Click the **Shadow tool**  button and move it so that it does not cover the map,
3. Then click the **DynaShade** button

You will now be able to interactively change the shadow angle [i.e., inclination and declination] and observe the outcome.

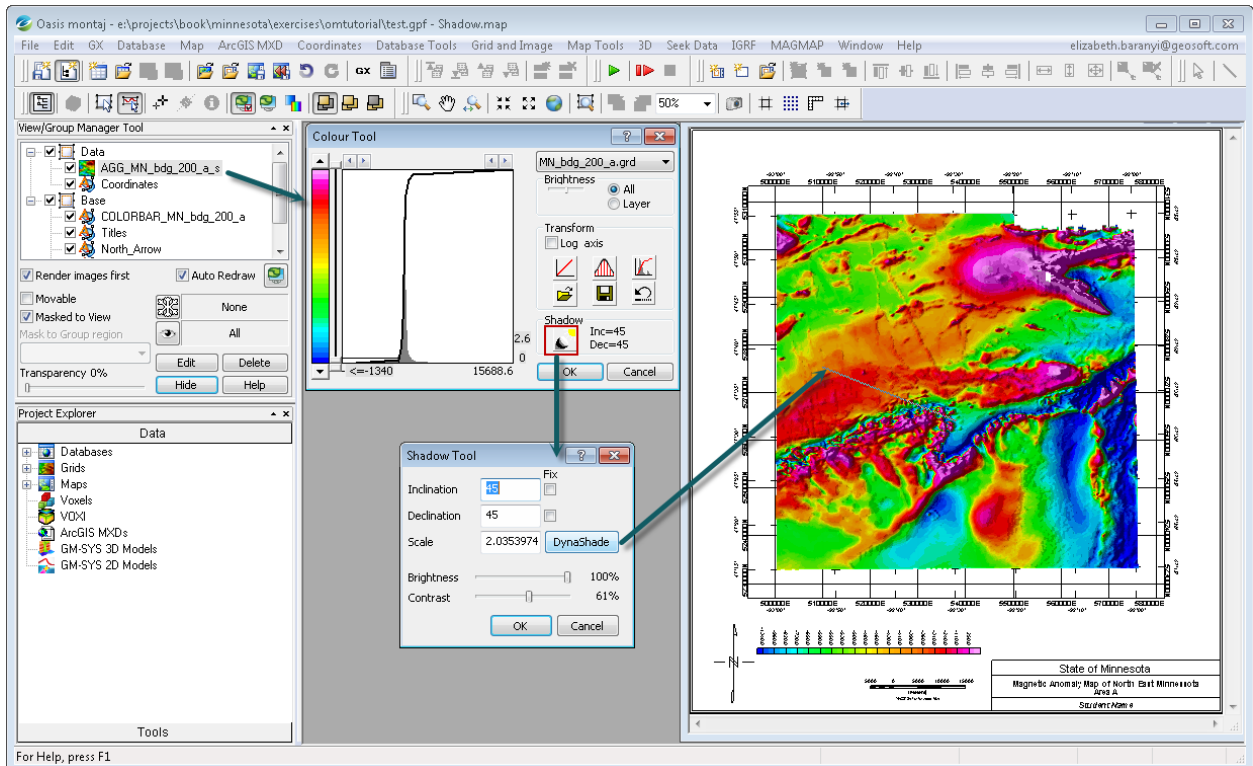


Figure 14: Process to modify the sun angle for optimal visual effect.

Colour Zone

Before adding the 100-metre gridded data to the map, save the colour scheme of the current grid in a zone file and use it to display the 100-metre grid, so that each colour represents the same data value bin, and you can directly compare the 2 grids. Use the settings shown in *Figure 7*.

1. From the **Map Tools** menu, click **Grid and Image**, then **Display** and then **Create Colour Zone File**. Specify the following settings:
 - Set **Output colour zone file**: *MN_Mag.zon*
 - Set **Grid name 1**: *MN_bdg_200_A*
 - Set **Colour table**: *colour.tbl*
 - Set **Coloring method**: *Histogram equalization*
 - Set **Contour interval**: *10*
 - Leave the other fields blank
2. Click **OK** to save the colour breaks and their equivalent magnetic values.

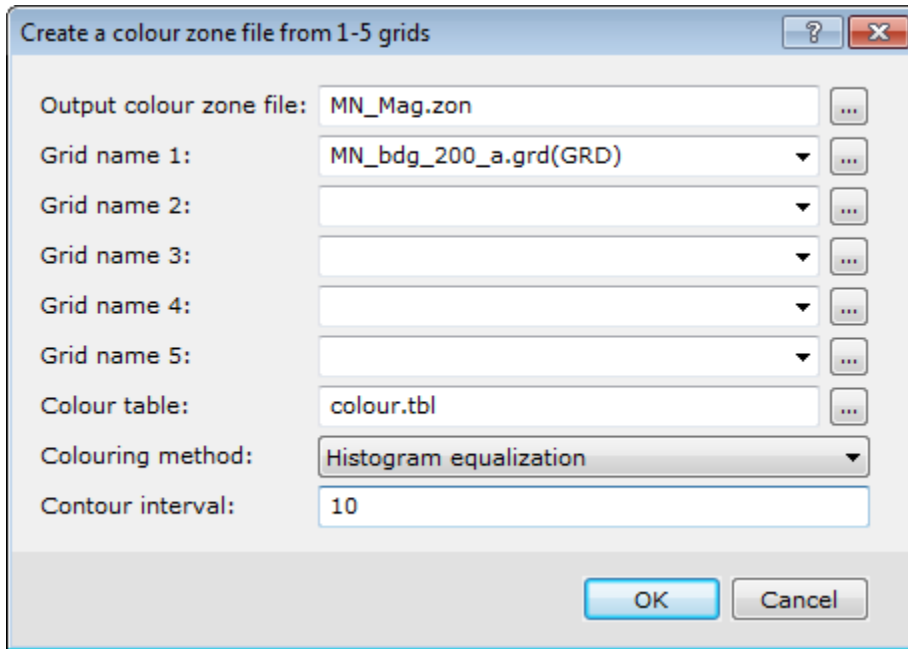


Figure 15: Template for creating zone files to specify color-fill tables for representing the gridded data.

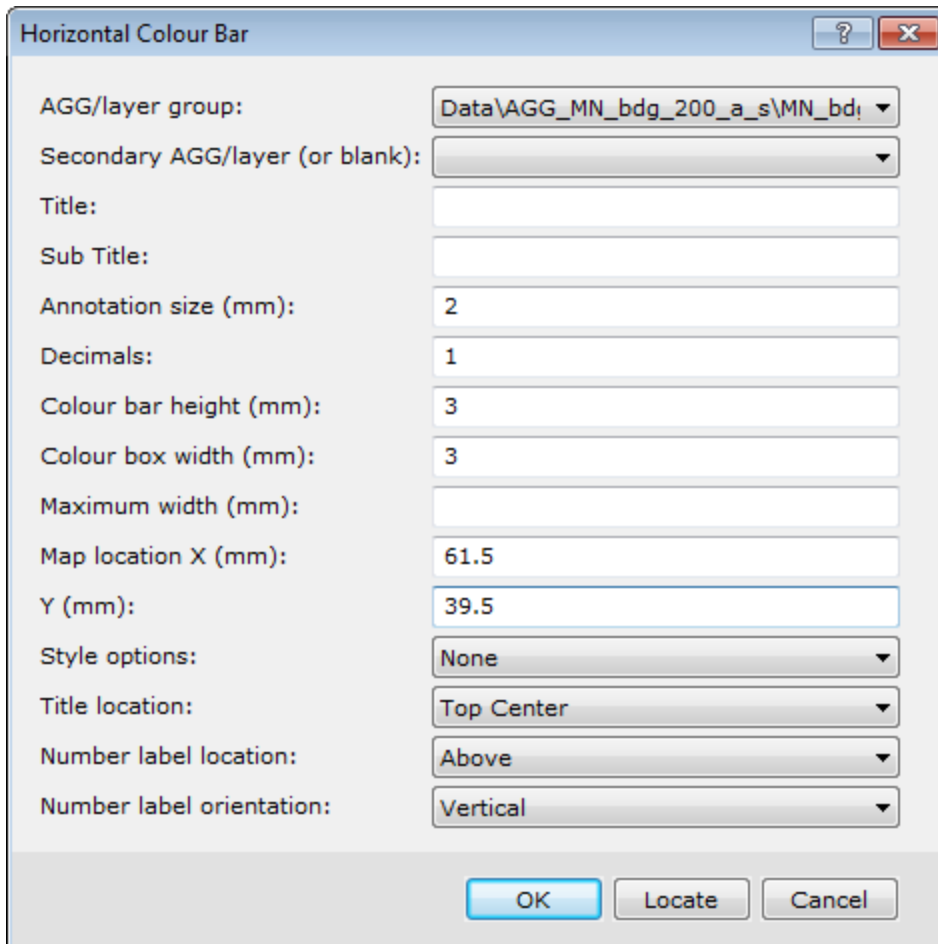
Display the 100-m cell size data grid *MN_bdg_100_A* on the same map, but this time using the colour zone file you just saved. To do so instead of using the colour table *colour.tbl*, select from your working folder the file *MN_Mag.zon*. Note that you will have to filter the files types for *.zon.

- ✏ The data view contains the coordinates as well as the 2 grids you just displayed. To see them in the View/Group Manager Tool, expand Data. All colour objects are preceded by AGG. The _s suffix indicates that this is a shaded image. The visible image is the one at the top of the list. To see the next image, either uncheck the topmost image, or simply drag the lower image to the top. You can also change the transparency of the top-most image to allow the lower image to emerge.

The data grid may also be displayed without shading. From the **Map Tools** menu, click **Grid and Image**, then click **Display**, and then **Single Grid**.

To include a horizontal color-bar on a map plot:

1. From the **Map Tools** menu, click **Symbols**, then **Horizontal Colour Legend Bar**. This displays a template with the settings indicated in *Figure 16*.




The image shows a dialog box titled "Horizontal Colour Bar". It contains several settings for configuring a color bar on a map. The settings are as follows:

Setting	Value
AGG/layer group:	Data\AGG_MN_bdg_200_a_s\MN_bdg_200_a_s
Secondary AGG/layer (or blank):	
Title:	
Sub Title:	
Annotation size (mm):	2
Decimals:	1
Colour bar height (mm):	3
Colour box width (mm):	3
Maximum width (mm):	
Map location X (mm):	61.5
Y (mm):	39.5
Style options:	None
Title location:	Top Center
Number label location:	Above
Number label orientation:	Vertical

At the bottom of the dialog box are three buttons: "OK", "Locate", and "Cancel".

Figure 16: Place colour scale on the map.

2. Select the colour image **AGG/layer group** to *MN_bdg_200_A*. Make sure you are not selecting the shadow image with the *_s* suffix.
3. Set the **Colour bar height** to 3 mm.
4. Set the **Colour box width** to 3 mm.
5. Set **Number label orientation** to *Vertical*
6. Click **Locate** to position the left end of the color-bar on the plot's coordinates in mm as indicated in *Figure 13*.

 To measure the distance on the map:

1. Right-click anywhere on the map and select **Ruler**.
2. Click on the first point on the map marking an end of the line segment, and then as you move the mouse notice the cumulative distance at the bottom-right end of the status bar. Click on the second point to measure the distance along a curvilinear line.

3. To finish, right-click and select **Done**.

- ✎ The indicated units will correspond to the selected object (*Data* or *Base*) .
- ✎ The distance between the last two consecutive points will appear in the corresponding spatial units in the bottom-left of status bar as marked by the red arrow of the example in *Figure 17*.
- ✎ Zoom on the scale bar and note that the color break intervals are indeed multiples of 10 nT.

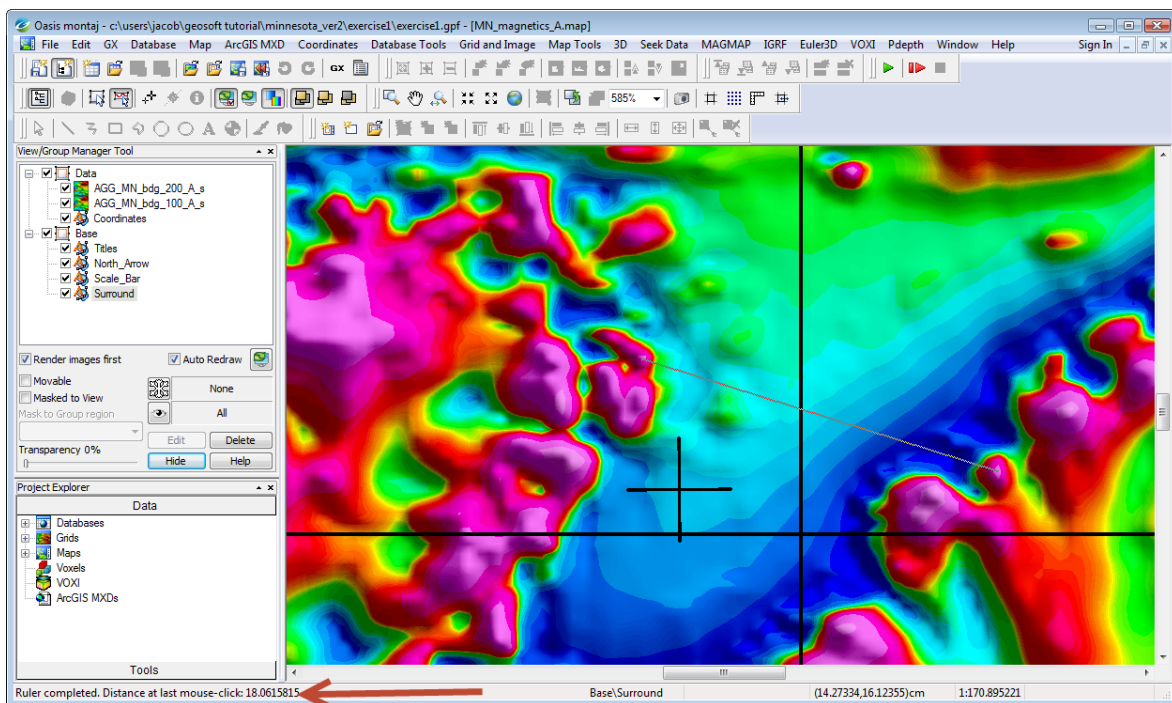


Figure 17: *Oasis montaj* window displaying a measured distance on a zoomed-in portion of the colour map.

Comparing Maps

Comparing maps is greatly facilitated by plotting the differences between 2 grids. Consider, for example, using the minimum curvature method [Hinze et al. (2013), Appendix A.6.2] to grid the RESIDMAG channel at a 200-m interval for comparison with the bi-directionally gridded data in *Figure 7*.

1. From the **Grid and Image** menu, click **Minimum Curvature**.
2. Select the **Channel to grid** as *RESIDMAG*
3. Set the **Name of new grid file** *MN_mc_200_A*
4. Set the **Grid cell size** to 200

Normally the grid cell size is automatically calculated, but to maintain the exact interval as the earlier gridded image override this entry. There are additional parameters that you can set by clicking on the **Advanced** button, but for now we will accept their default values. The minimum curvature template and output data grid are illustrated in *Figures 18* and *19*, respectively.

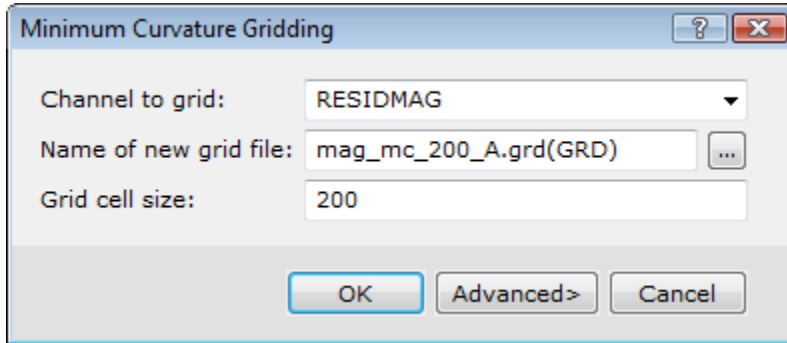


Figure 18: Minimum curvature gridding.

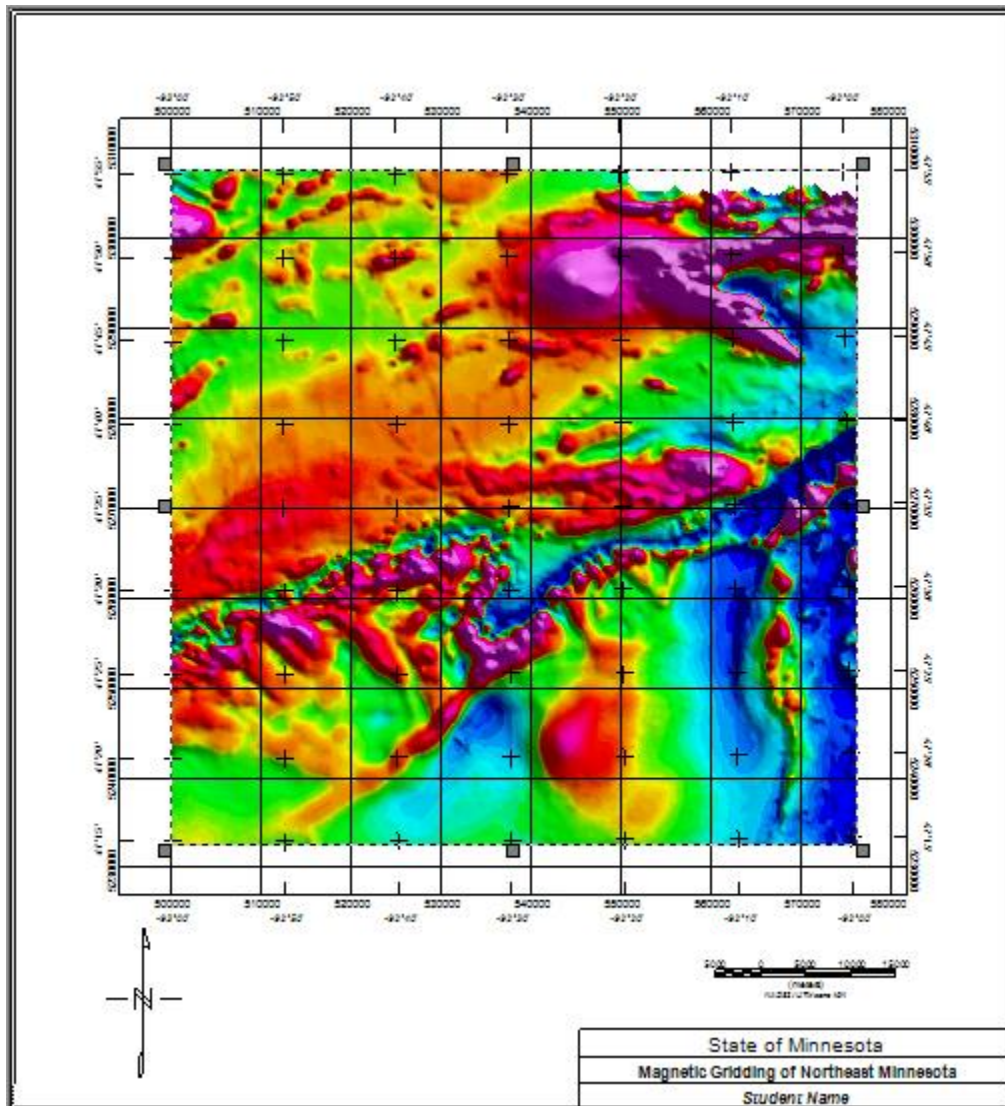


Figure 19: Aeromagnetic anomaly data for study area A gridded using the minimum curvature algorithm.

To compare the effects of bi-directional versus minimum curvature gridding, the difference in the two grids can be taken using the *Grid Math Expression Builder* template [Figure 21].

1. From the **Grid and Image** menu, click **Grid Math**. Enter the following settings:
 - Set **Expression**: $G0 = G1 - G2$
 - Set **Assign grids**: $G0 = MN_diff_bdg_mc_200_A$
 - Set **Assign grids**: $G1 = MN_bdg_200_A$
 - Set **Assign grids**: $G2 = MN_mc_200_A$
2. Clicking **OK** results in the grid displayed on the map of Figure 20, which shows the differences in subtracting the minimum curvature grid predictions [Figure 19] from the bi-directional grid estimates [Figure 7].

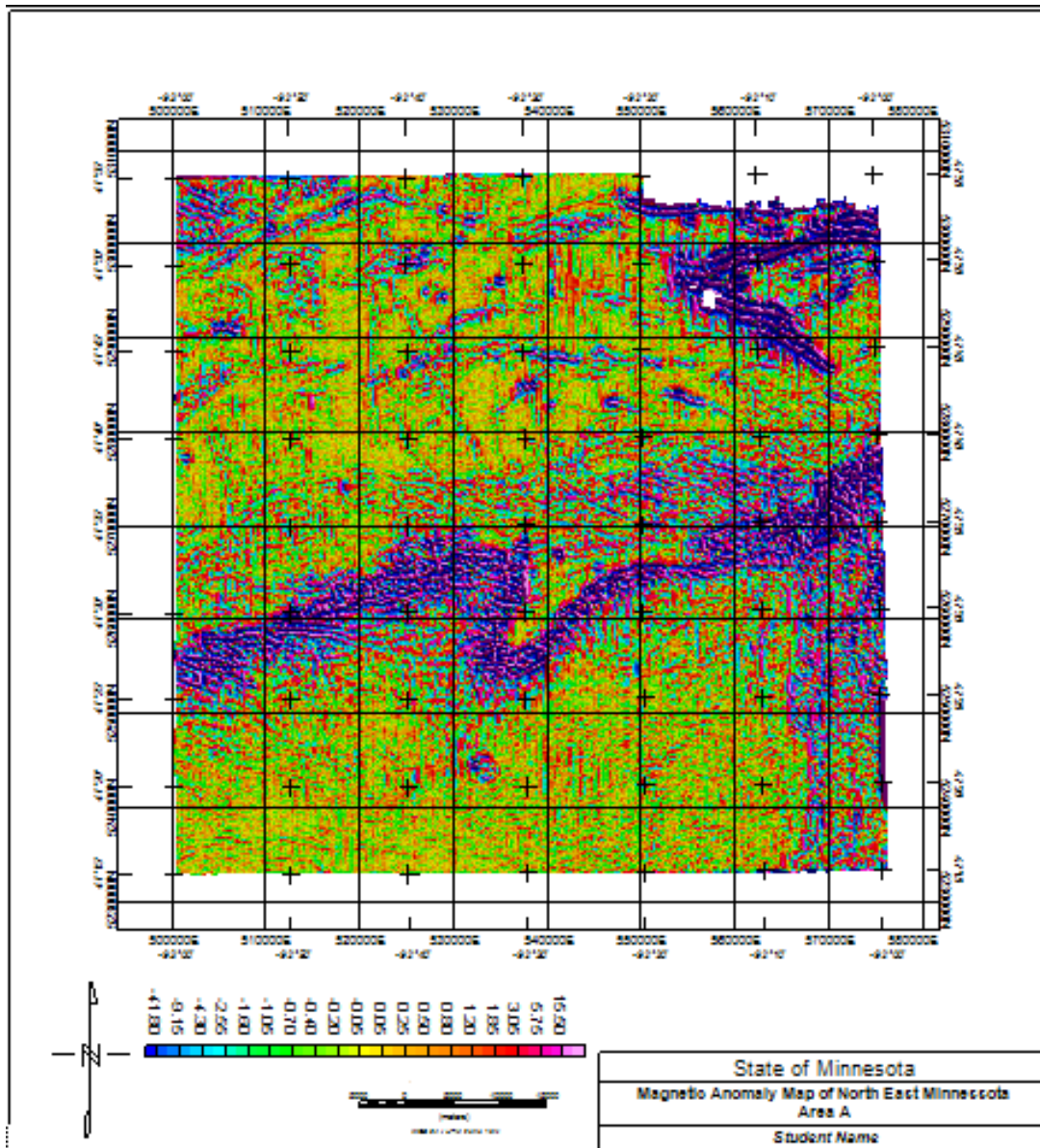


Figure 20: Differences in gridding the aeromagnetic anomaly data for study area A [Figure 1] obtained from subtracting the minimum curvature estimates from the bi-directional estimates at a 200-m grid interval.

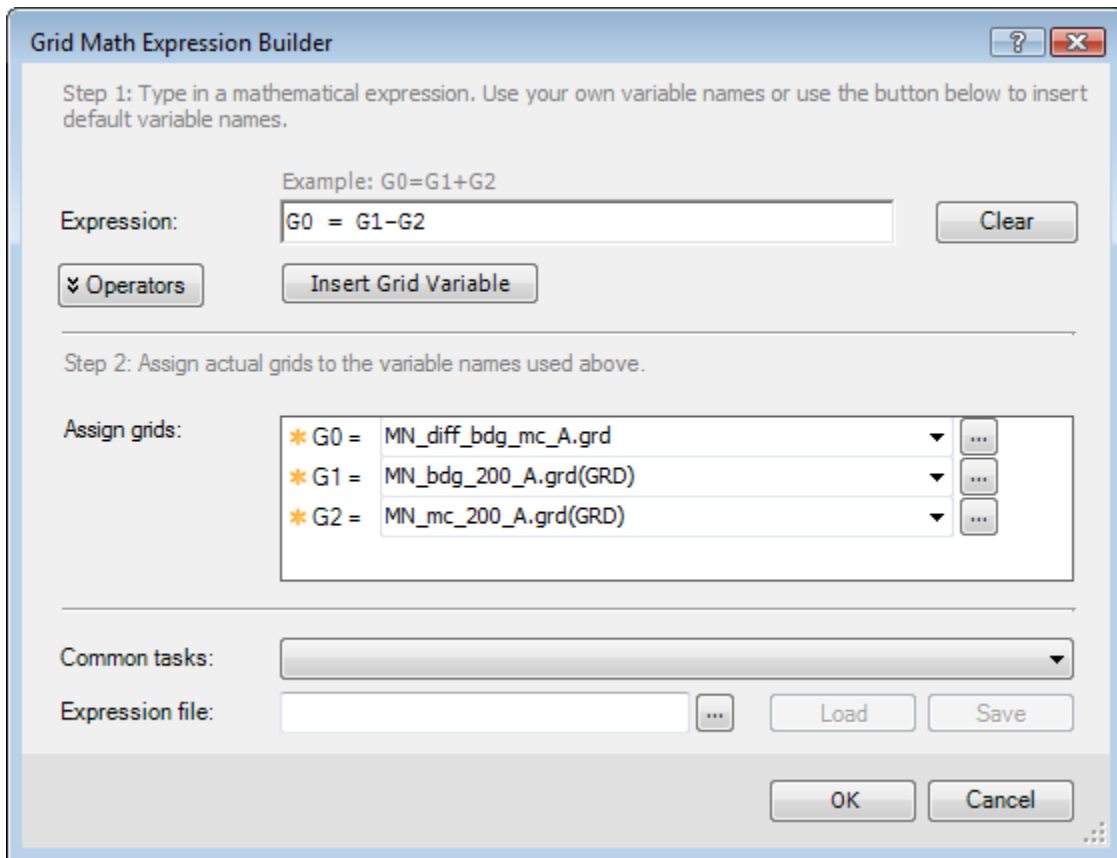
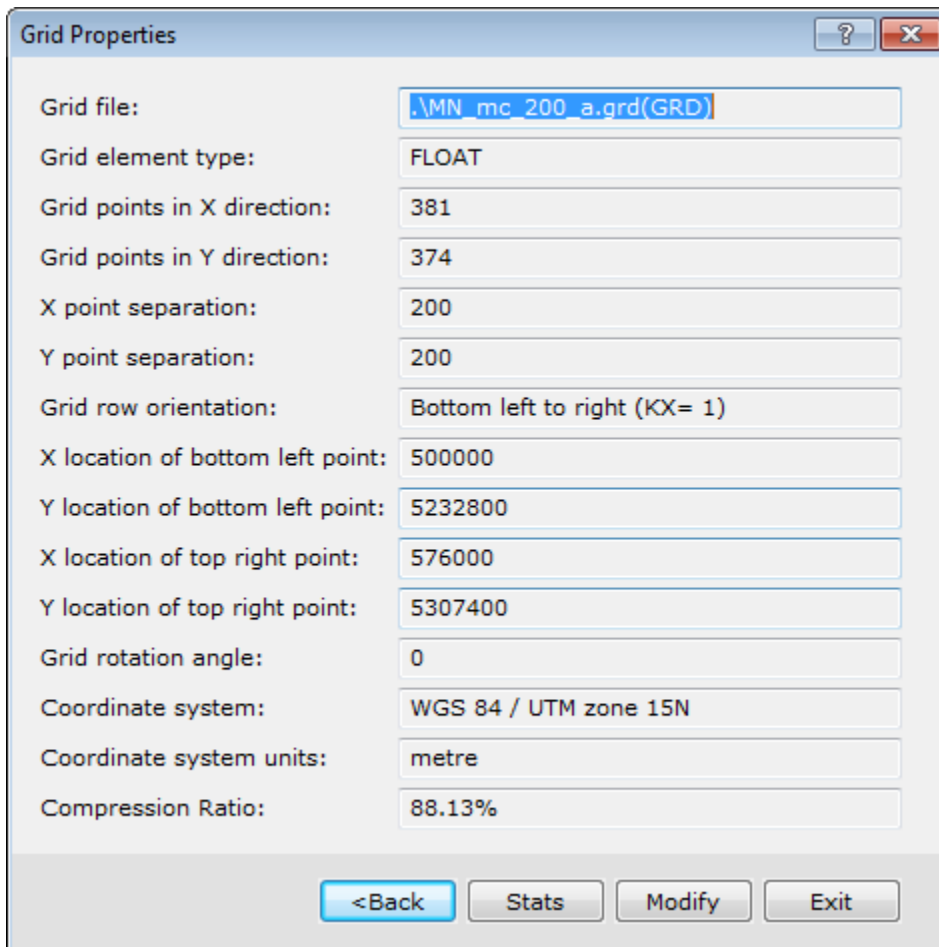


Figure 21: Grid math expression builder template for mathematical manipulating data grids.

To view the statistical attributes of a grid:

1. From the **Grid and Image** menu, click **Properties**.
2. Select the grid file to view. For example, selecting *MN_mc_200_A.grd* [Figure 19] brings up the template in Figure 22.




Property	Value
Grid file:	.\MN_mc_200_a.grd(GRD)
Grid element type:	FLOAT
Grid points in X direction:	381
Grid points in Y direction:	374
X point separation:	200
Y point separation:	200
Grid row orientation:	Bottom left to right (KX= 1)
X location of bottom left point:	500000
Y location of bottom left point:	5232800
X location of top right point:	576000
Y location of top right point:	5307400
Grid rotation angle:	0
Coordinate system:	WGS 84 / UTM zone 15N
Coordinate system units:	metre
Compression Ratio:	88.13%

Buttons: <Back, Stats, Modify, Exit

Figure 22: Grid properties.

3. Click **Stats** to view the statistical attributes of the grid [Figure 23].

At first sight you may perceive that the difference is very large. By default the color distribution is set to cover the entire data distribution, no matter its range. If you inspect the statistics of either the bi-directional magnetic grid or the minimum curvature grid and compare its standard deviations with that of the difference grid, you will notice that the difference grid is no more than 8% of the actual magnitude of the magnetic data distribution. The standard deviation of the difference grid is 66 nT while the standard deviation of either gridded magnetic data is in the order of 835 nT. This difference is negligible along the survey lines but will vary in the space between the lines.

 Click **Help** to see a further explanation of the attributes.

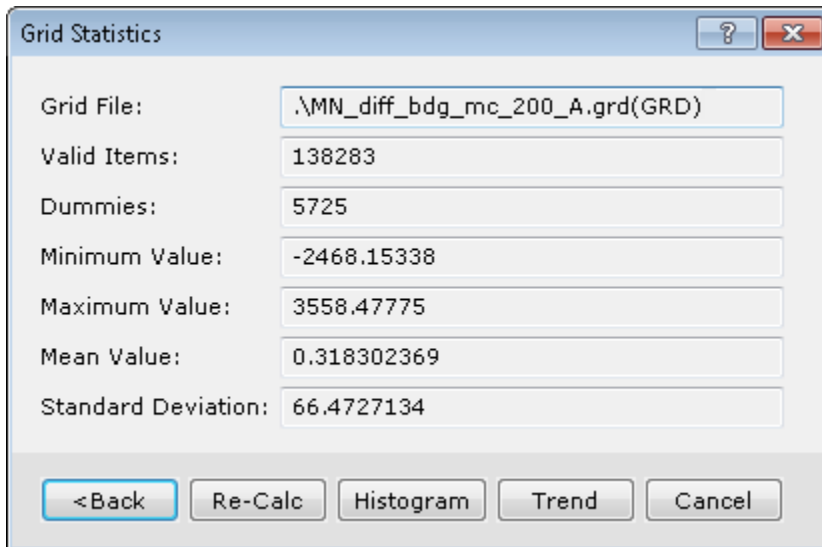


Figure 23: Grid property attributes.

Geomagnetic Field

To evaluate the geomagnetic field [see Hinze et al. (2013), section 12.3.1], *Oasis montaj* offers the IGRF and MAGMAP menus.

1. On the **GX** menu, click **Load Menu** and select **igrf.omn** from the list to load it on the menu bar.
2. On the **IGRF** menu, click **IGRF Channel** to bring up the template in *Figure 24*.
 - Set **IGRF model year**: 1985
 - Set **Survey date**: 1985/05/01
 - Set **Longitude**: *Longitude*
 - Set **Latitude**: *Latitude*
 - Set **Elevation**: *Altradar*
 - Set **Ouput channels**: *TotFld, Inc, Dec*
3. Click **OK** to obtain three new output channels listing the desired geomagnetic field attributes. *TotFld, Inc, Dec* illustrated on *Figure 25*.

Compute GRF Channels

IGRF or DGRF: DGRF

IGRF Model year (ignored for DGRF): 1985

Survey date: Single string YYYY/MM/DD or Channel name or Blank (to use line date): 1985/05/01

Input channels: -- Longitude: LONGITUDE

-- Latitude: LATITUDE

Elevation (Channel name OR single value): ALTRADAR

Output channels: -- Total field: TotFld

-- Inclination: Inc

-- Declination: Dec

OK Cancel

Figure 24: Compute DGRF template to evaluate total field intensity, inclination, and declination values for the DGRF on 1985/05/01 [May 1, 1985] at the database coordinates.

MN_Mag_A.gdb

L1:1:0	Latitude	Longitude	AltRadAr	TotFld	Inc	Dec	UTME N83	UTMN N83	AltBaro	TotalMag	ResidMag	VertDer
0.0	47.15.03.66	-92.17.23.48	567.2	59409.9	74.92248	2.31138	553737.34	5233303.86	1783.08	59613.98	-524.75	-0.83
1.0	47.15.05.35	-92.17.23.42	572.7	59409.9	74.92283	2.31121	553736.44	5233356.02	1804.14	59614.98	-523.89	0.50
2.0	47.15.07.03	-92.17.23.45	569.0	59410.2	74.92318	2.31112	553735.34	5233407.88	1804.14	59615.98	-523.04	0.65
3.0	47.15.08.75	-92.17.23.47	574.5	59410.1	74.92353	2.31103	553734.44	5233460.97	1814.71	59616.40	-522.69	0.16
4.0	47.15.10.44	-92.17.23.50	570.9	59410.4	74.92388	2.31095	553733.33	5233513.14	1814.71	59616.40	-522.84	-0.81
5.0	47.15.12.12	-92.17.23.57	572.7	59410.5	74.92423	2.31087	553731.39	5233564.98	1825.29	59616.40	-522.99	-1.81
6.0	47.15.13.81	-92.17.23.59	576.3	59410.5	74.92457	2.31078	553730.49	5233617.15	1814.71	59616.90	-522.63	-2.43
7.0	47.15.15.49	-92.17.23.62	572.7	59410.8	74.92493	2.31070	553729.39	5233669.08	1825.29	59617.40	-522.28	-2.65
8.0	47.15.17.17	-92.17.23.64	567.2	59411.1	74.92528	2.31061	553728.58	5233720.86	1835.86	59618.40	-521.43	-2.86
9.0	47.15.18.86	-92.17.23.67	561.8	59411.5	74.92564	2.31053	553727.39	5233773.02	1835.86	59619.40	-520.58	-3.48
10.0	47.15.20.54	-92.17.23.74	552.7	59411.9	74.92599	2.31046	553725.45	5233824.87	1835.86	59620.90	-519.23	-4.11
11.0	47.15.22.23	-92.17.23.77	543.6	59412.3	74.92635	2.31037	553724.35	5233877.04	1825.29	59622.40	-517.87	-4.37
12.0	47.15.23.91	-92.17.23.79	558.1	59412.0	74.92668	2.31028	553723.45	5233928.89	1804.14	59625.40	-515.02	-3.56
13.0	47.15.25.68	-92.17.23.82	550.9	59412.4	74.92704	2.31020	553722.35	5233981.06	1835.86	59629.40	-511.17	-1.65
14.0	47.15.27.28	-92.17.23.84	552.7	59412.5	74.92739	2.31011	553721.46	5234032.91	1804.14	59632.90	-507.82	0.62
15.0	47.15.29.08	-92.17.23.91	549.0	59412.8	74.92775	2.31003	553719.58	5234086.08	1804.14	59636.40	-504.46	2.18
16.0	47.15.30.68	-92.17.23.94	550.9	59412.9	74.92809	2.30995	553718.48	5234137.85	1825.29	59639.40	-501.61	2.37
17.0	47.15.32.37	-92.17.23.96	549.0	59413.1	74.92844	2.30986	553717.58	5234190.02	1814.71	59641.40	-499.76	1.50
18.0	47.15.34.05	-92.17.23.99	540.0	59413.5	74.92880	2.30978	553716.48	5234241.87	1825.29	59642.40	-498.91	0.59
19.0	47.15.35.61	-92.17.24.01	558.1	59413.1	74.92911	2.30969	553715.54	5234298.03	1804.14	59644.90	-496.55	0.52

Chan

Figure 25: Total field intensity, inclination & declination values for the DGRF on 1985/05/01 [May 1, 1985] at the database coordinates.

Filtering

Data filtering is used extensively to isolate and enhance anomaly features of interest to interpretation. The applications and mathematical principles of magnetic anomaly filtering are outlined respectively in Chapter 12.4 and Appendix A.5 of Hinze et al. (2013). Examples of the numerous magnetic data filtering operations offered by *Oasis montaj* are outlined below.

Reduction-to-Pole [RTP] Filter

Both the reduction-to-pole [RTP] and differential reduction-to-pole [DRTP] filters are available. If the study region spans less than 2° , you can safely use the faster former method. To RTP-filter the minimum curvature grid in file MN_mc_200_A.grd

1. On the **MAGMAP** menu, click **MAGMAP 1-Step Filtering**. To open and set the dialogue box shown in *Figure 26*.
 - Specify the **input grid** as *MN_mc_200_A.grd*
 - Specify *MN_RTP_A.grd* as the **Output grid**
 - Specify *RTP* as the **Filter control file**

It is recommended to save the pre-processed interim grid files to reduce computation time when applying another filter to the same grid file.

2. Click **Filter** and the template in *Figure 27* will appear
3. From the drop-down list of Filter 1, select **Reduce to magnetic Pole**

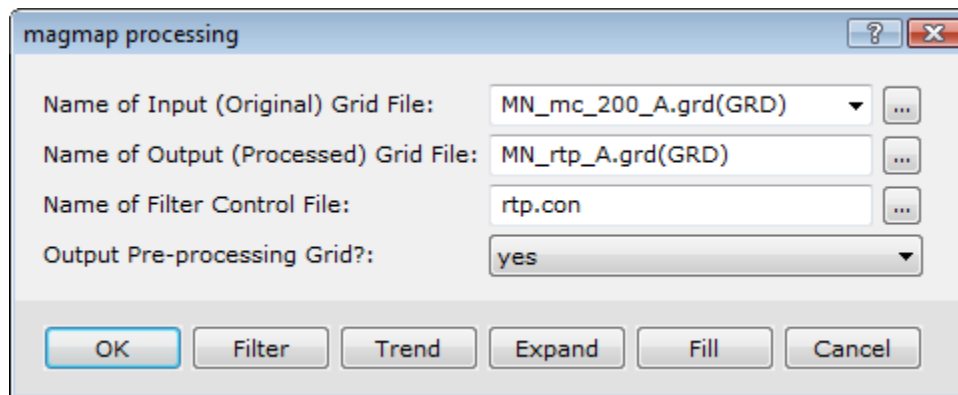



Figure 26: Magmap processing template set to RTP filter the minimum curvature grid plotted in Figure 18.

4. Enter the survey date of 1985/05/01 and press on the calculator button  to automatically calculate the required fields for the reduction to the pole.

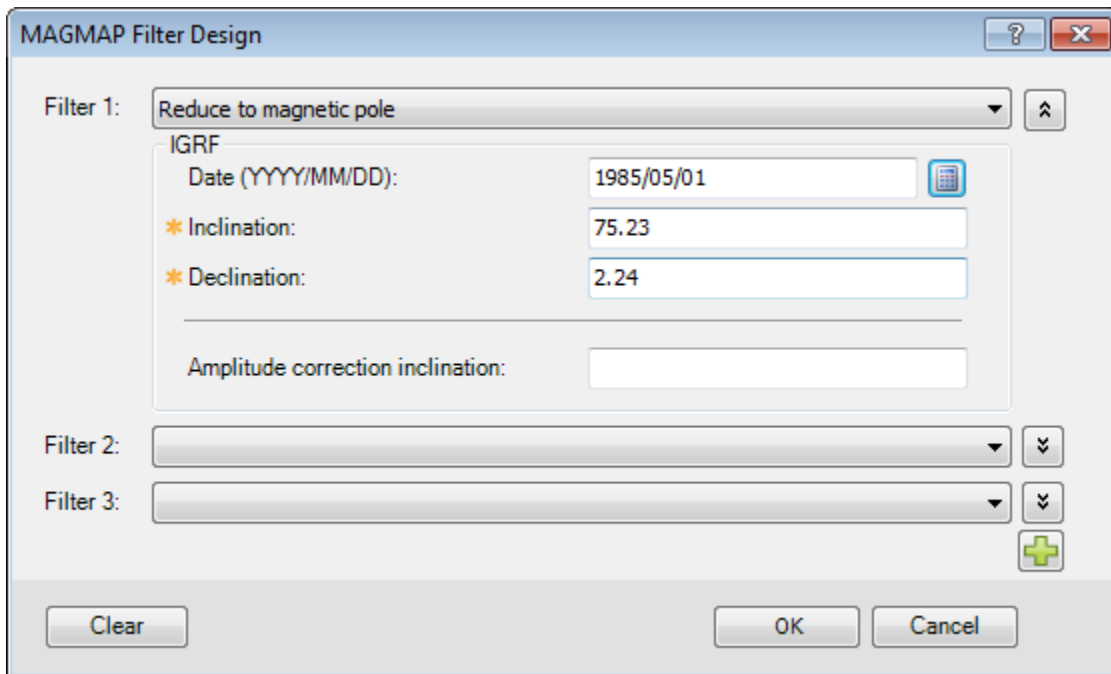


Figure 27: MAGMAP Filter Design template set to reduce to magnetic pole the minimum curvature estimates plotted in Figure 18 at the Inclination and Declination values evaluated from the GRF.

5. Click **OK** to save the parameter file and to go back to the main MAGMAP processing template [Figure 26], then
6. Click **OK** to yield the output file *MN_rtp_A.grd*.

Add the filtered output grid to the map:

1. Select the existing **MN magnetic Anomaly A.map**. If the map is not loaded, simply drag-and-drop it from the Project Explorer box at the lower left into the main *Oasis montaj* window.
2. When loading the grid into the map, use the existing *MN_Mag.zon* colour file so that you can directly compare the pole reduced anomaly grid with the initial minimum curvature grid.
 - ✎ To get an appreciation of the effect of reduction to the pole, check on and off the topmost RTP grid to toggle between viewing the RTP and the residual anomaly grid.
 - ✎ You can also zoom on a local anomaly and then toggle the view. To zoom in right-click anywhere on the map and select *Zoom box*. Then proceed by drawing the area to zoom in.

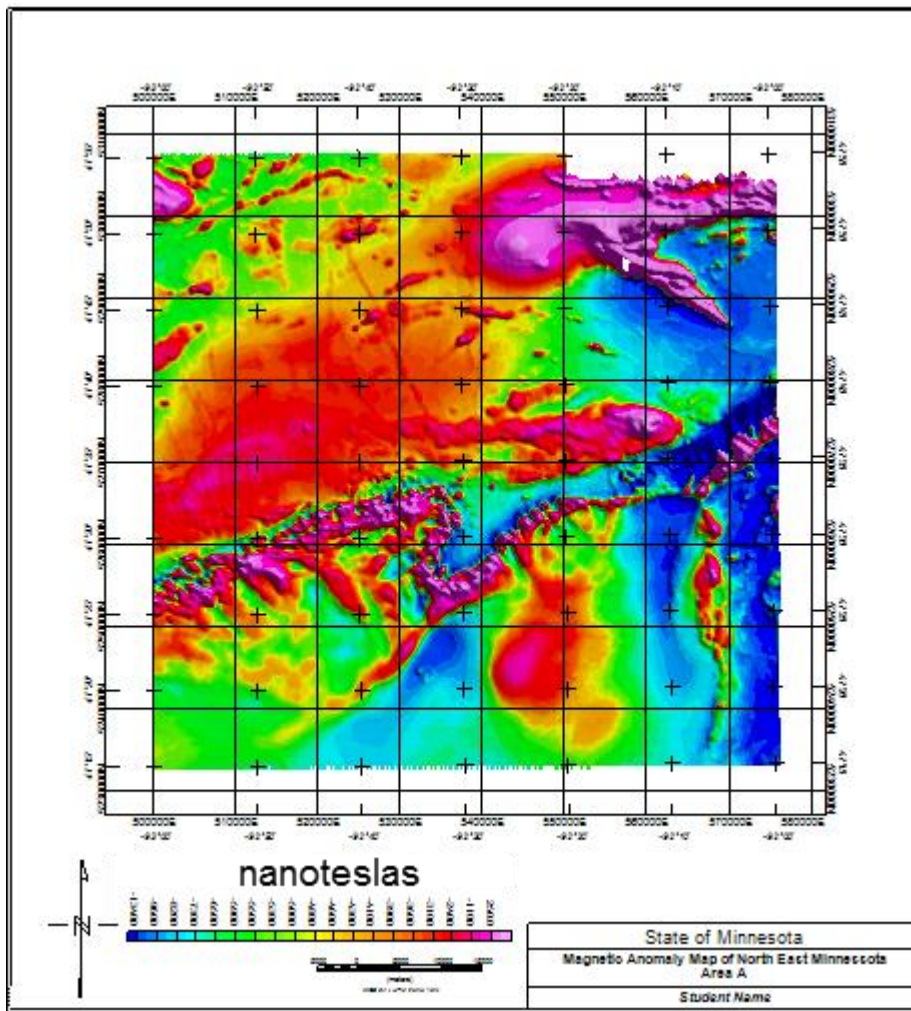


Figure 28: Pole reduced (RTP) magnetic anomaly map of the minimum curvature estimates in Figure 19.

Derivative Filters

Oasis montaj offers capabilities to take the vertical and horizontal derivatives of the data grid. For example, to calculate the first vertical derivative of the RTP-grid,

1. From the **MAGMAP** menu, click **1-Step Filtering...** to bring up and set the template in *Figure 26*.
 - Specify *MN_RTP_A.grd* as the **Input grid**
 - Specify *MN_RTP_1vd_A.grd* as the **Output grid**
 - Specify the Filter control file as *1VD*.
2. Click **Filter** to bring up and set the template
3. From the drop down list of Filter 1 select *Derivative*
4. Click on the **Z** radio button to indicate a vertical derivative.
5. Leave the Order of the differentiation at the default of 1 [*Figure 29*]
6. Click **OK**, which returns the magmap processing template, where a further

7. Click **OK** yields the output file *MN_RTP_1vd_A.grd*.

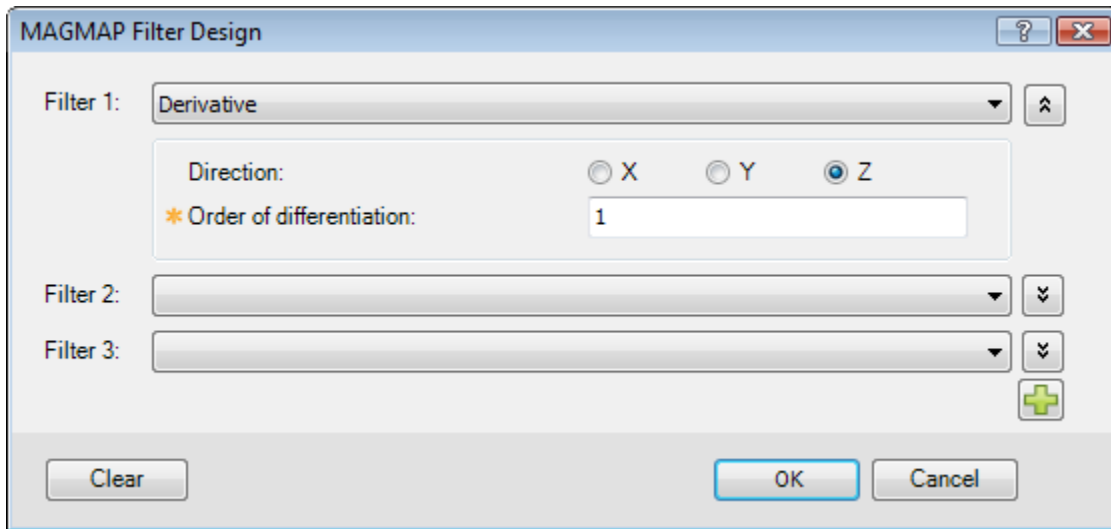


Figure 29: MAGMAP Filter Design template set to take the Derivative in the vertical [Z] direction of first order of the minimum curvature RTP estimates plotted in Figure 28.

Create a new map to display the derivative grid. The defaults previously used are still in effect and you will have to provide minimal entries.

1. From the **Map Tools** menu, click **New Map** and then click **Next**.
2. Name the map *MN RTP 1VD A.map*.
3. From the **Map Tools** menu, click **Base Map**. Then click **Next** and **Next** again.
4. Set the **Map title** to *Pole Reduced 1st Vertical Derivative of NE Minnesota*.
5. Click **Finish**.
6. Move the North arrow and Scale bar to the desired location
7. Display the pole reduced 1st vertical derivative grid. You will consider two differences from the previous approach:

The derivative values are in units of nT/m, the range of which is quite different from the Anomaly data distribution range. Leave the colour table dialogue blank to force the calculation of the colour levels according to the current data distribution.

- ✎ Set the Contour interval to 0.0025 to break the color levels at round numbers, and annotate the color bar with 4 decimals.

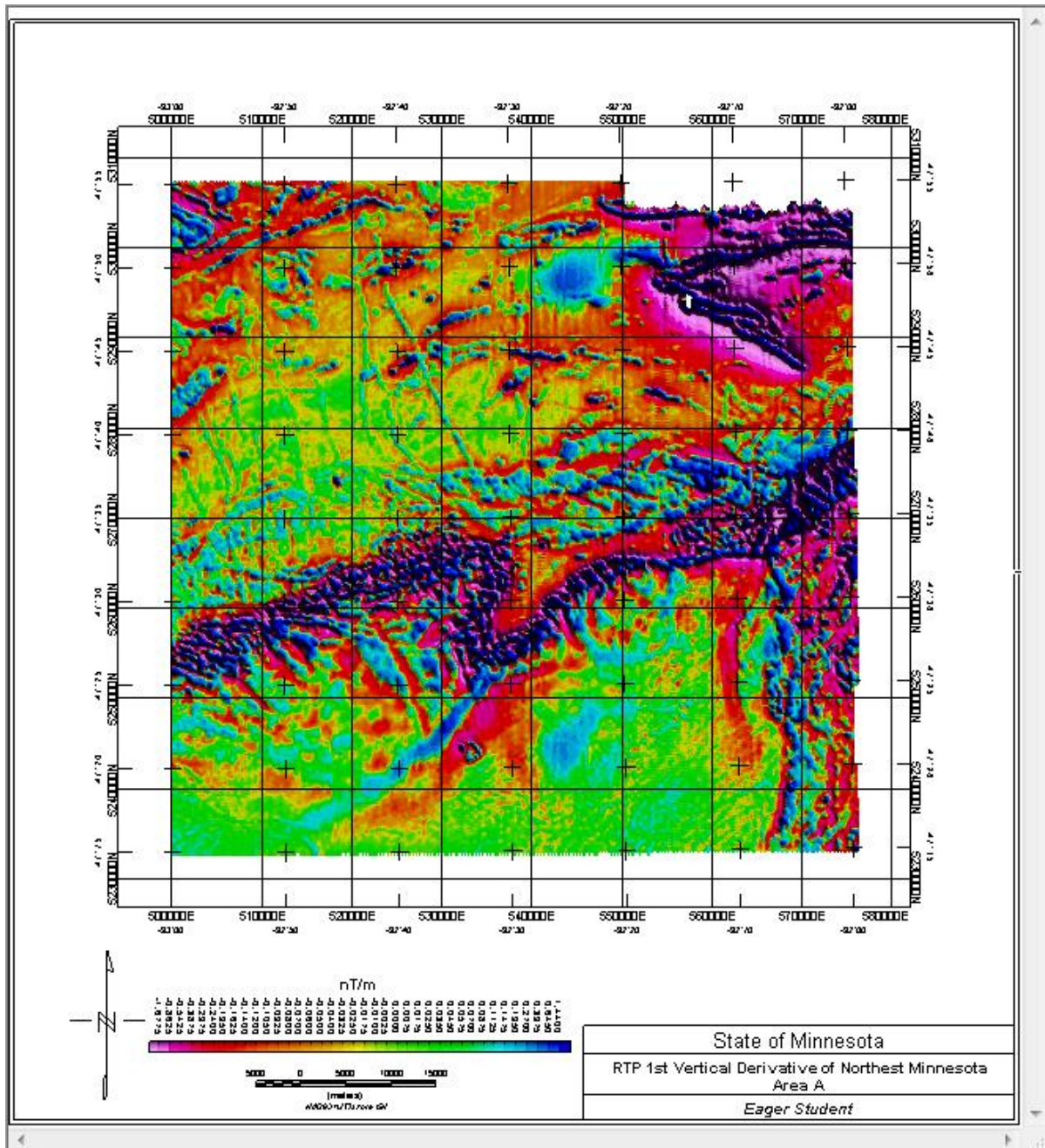


Figure 30: Pole reduced 1st vertical derivative map.

Composite Directional+Wavelength Filter

In the derivative map, you will not only notice high-frequency noise, but also striation that coincides with the general flight direction. Inherently the 1st vertical derivative filter accentuates and concentrates the structural features; but it also accentuates potential leftover noise from leveling in the data. You can now proceed to filter this undesirable striation and high-frequency noise simultaneously.

To pass or reject strike-sensitive anomaly features in the gridded data, *Oasis montaj* offers the directional cosine filter. Here, the filter wedge is constructed from the cosine function with smoothly tapering edges to better mitigate ringing and other Gibbs' errors in the output data. For an application to the pole reduced vertical derivative grid of *Figure 30*,

1. From the **MAGMAP** menu, click **MAGMAP 1-Step Filtering**. Specify the following settings:
 - Specify *MN_RTP_1VD_A.grd* as the **Input grid**.
 - Specify *MN_RTP_1vd_Clean_A.grd* as the **Output grid**.
 - Specify *DCos* as the **Filter control file**.

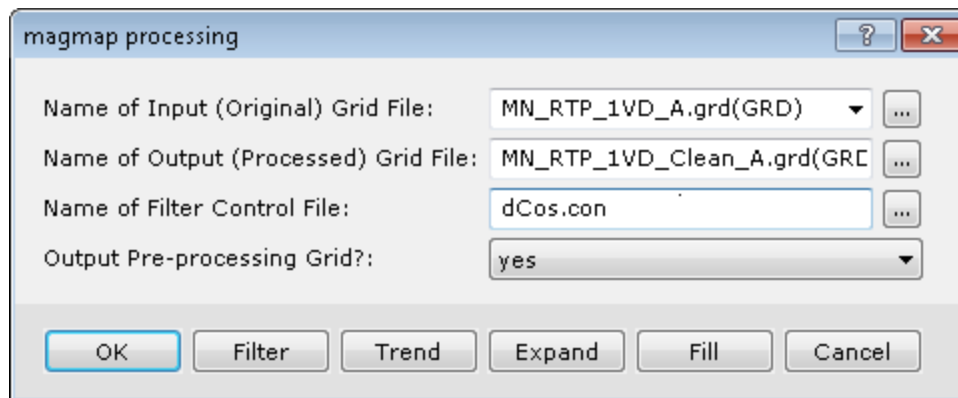


Figure 31: Magmap processing template set to apply a directional cosine filter [dcos.con] to the pole reduced 1st vertical derivative estimates plotted in Figure 30 with the output shown in Figure 33.

2. Click **Filter** to bring up and set the template.
3. From the drop down list of Filter 1 select *Directional cosine*.
4. The noise is in the NS direction so enter the **cutoff azimuth** of 0.
5. The **degree of the cosine function** indicates the degree of smoothness of the cutoff. Select 0.5.
6. **Reject** the defined high-frequency noise.

At the same time, since frequency domain filters are commutative, add a low pass Butterworth filter to reject any further noise in all other directions.

1. From the drop down list of Filter 2, select *Butterworth*.
2. Enter the **wavelength cutoff** of 400 metres, which is equivalent to two line spacings.
3. Select **Low pass**.
4. Click **OK**, which returns the magmap processing template, where a further
5. Click **OK** yields the output file *MN_RTP_1vd_Clean_A.grd*.

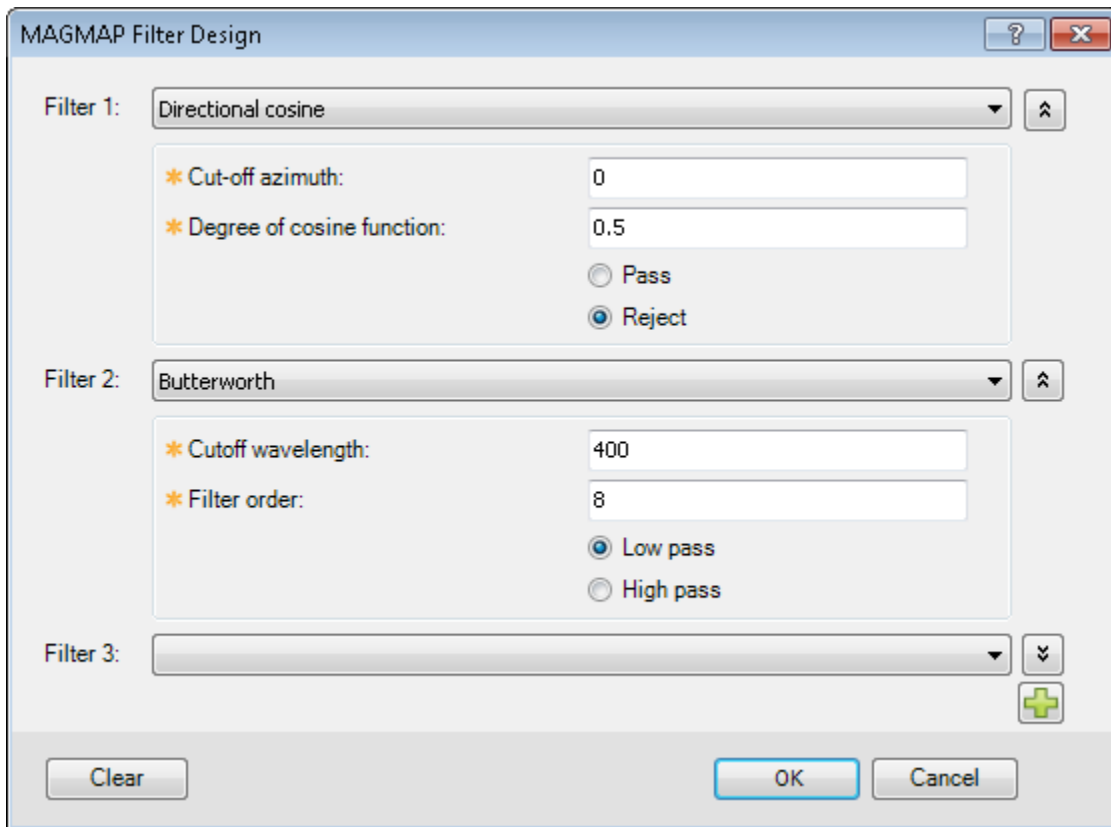



Figure 32: Noise reduction filter definition.

 Note the larger the Degree of cosine function is, the sharper the transition at the cutoff will be.

6. Add the filtered output grid to the map [again by selecting the *MN_RTP_1VD A.map* in the lower left Project Explorer box of the *Oasis montaj* window].

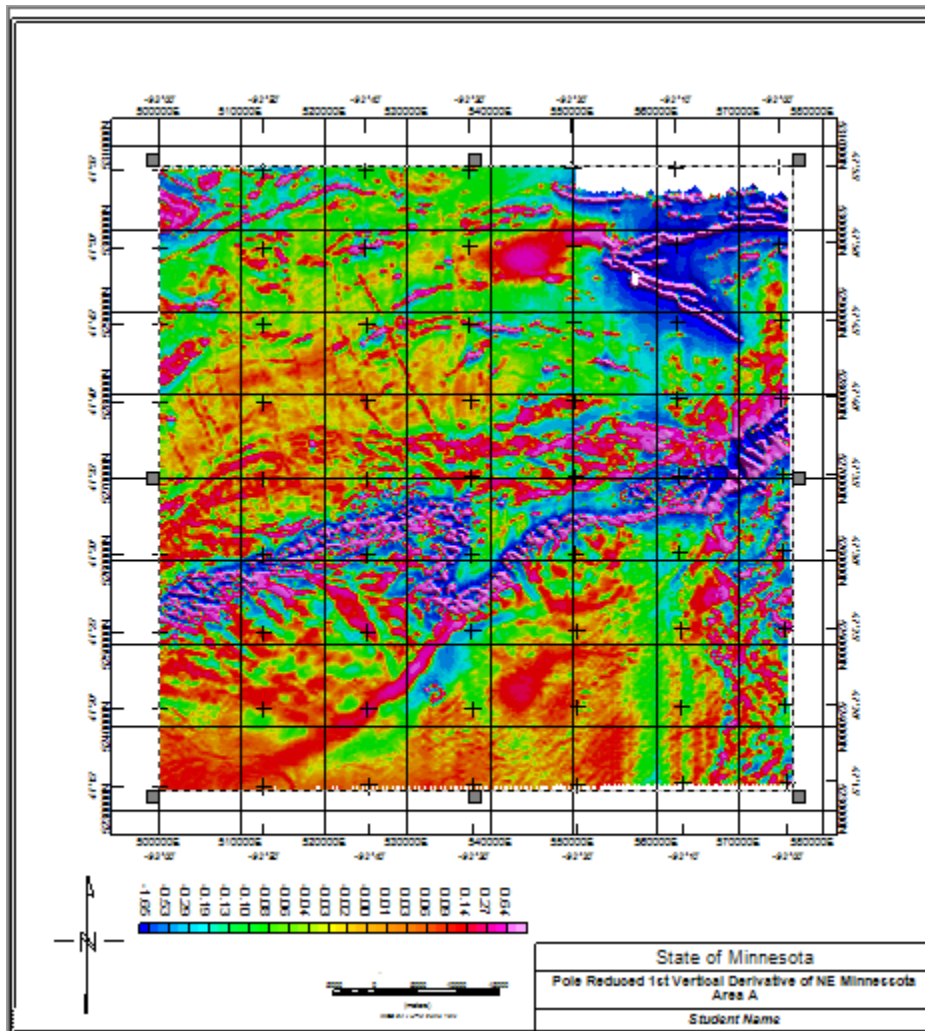


Figure 33: Noise filtered pole reduced 1VD anomaly map. Notice how the geologic structure is better isolated compared to Figure 30.

Continuation Filters

The procedures for all the other filters available in MAGMAP of *Oasis montaj* are the same. *Figure 34* shows the magmap processing and MAGMAP Filter Design template set to upward continue the pole reduced anomaly grid of area A to 1,000 m. Proceed to generate the upward continued anomaly grid and display it on the same map [*Figure 35*].

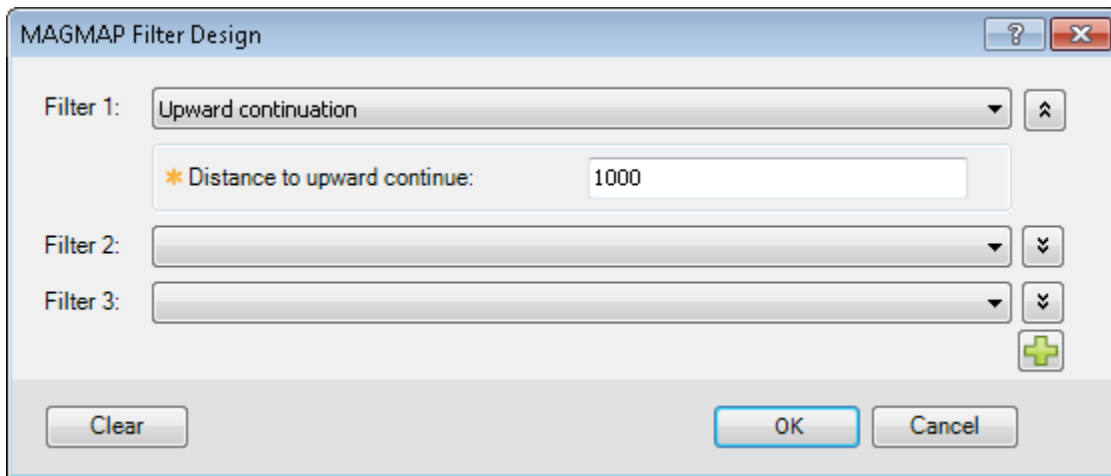


Figure 34: Upward continuation template.

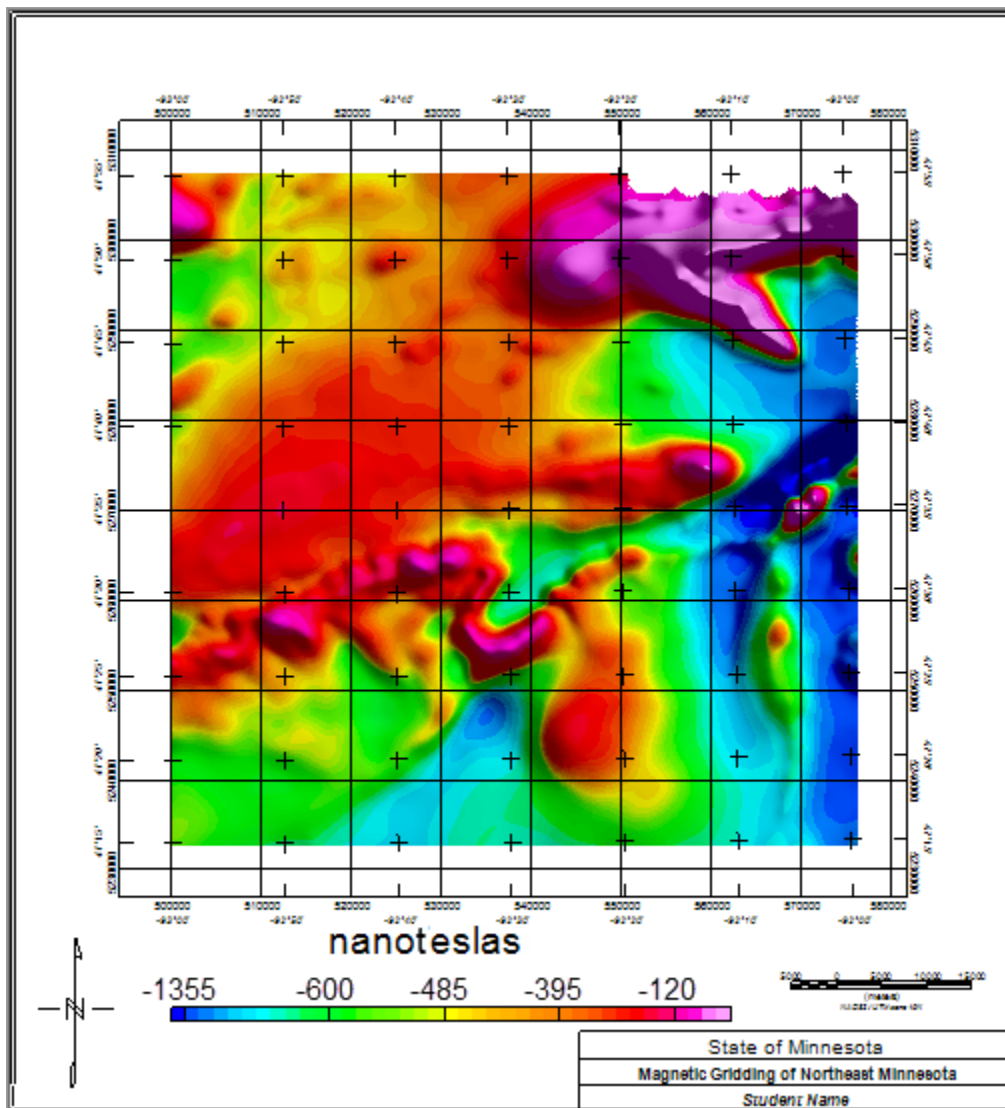


Figure 35: Pole reduced anomaly map upward continued 1,000 m.

Apparent Susceptibility Filter

Figure 36 shows the relevant templates for estimating the apparent susceptibility of the initial magnetic anomaly grid at a depth of 120 m.

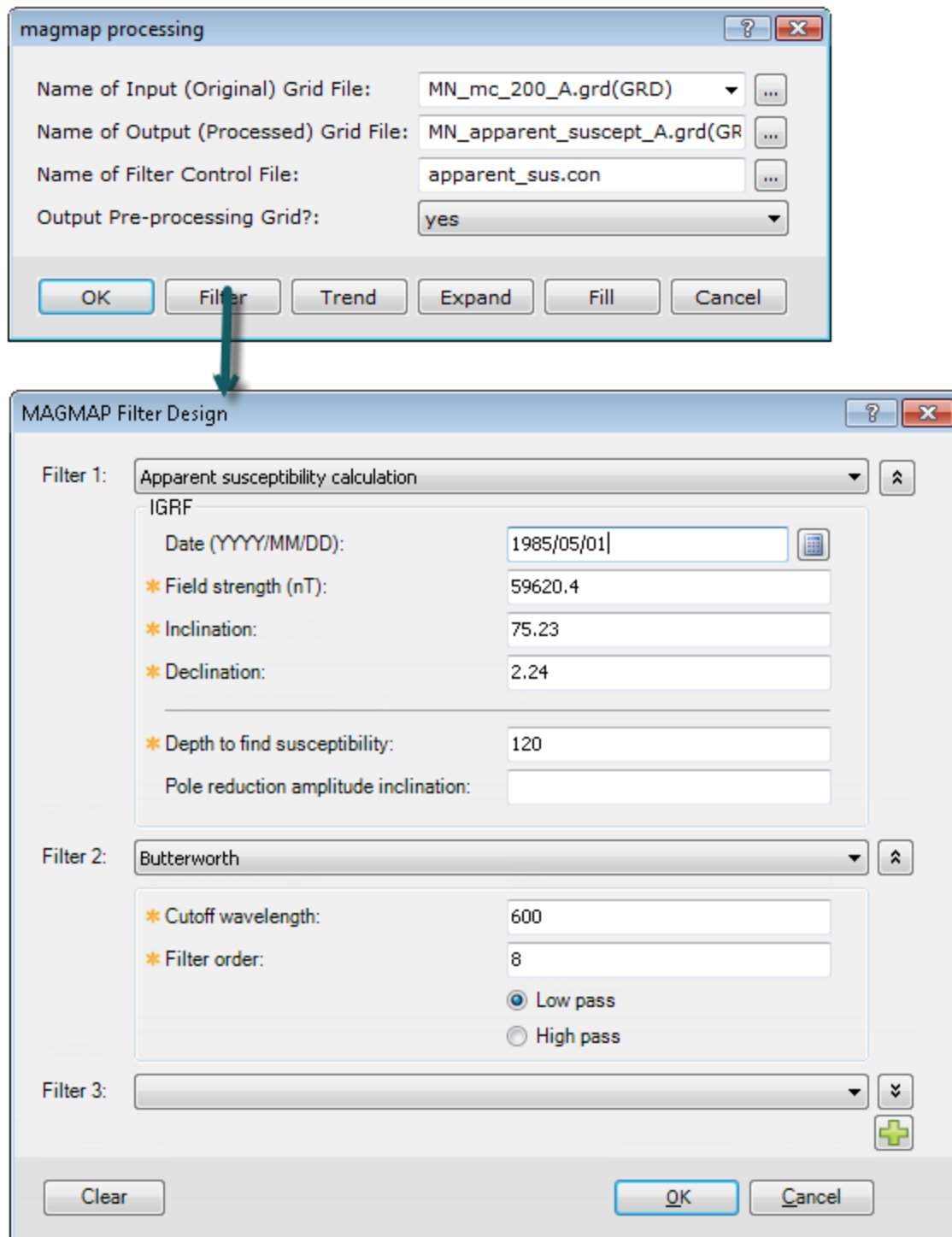


Figure 36: Apparent susceptibility calculation templates.

You can specify the approximate date of the survey and press the calculate button to generate the magnetic field strength [intensity], inclination, and declination values determined for the appropriate date.

Furthermore, since the apparent susceptibility is calculated at a depth of 120 m, a low pass filter is necessary to smooth out any potential high frequency noise resulting from intensifying surface anomalies.

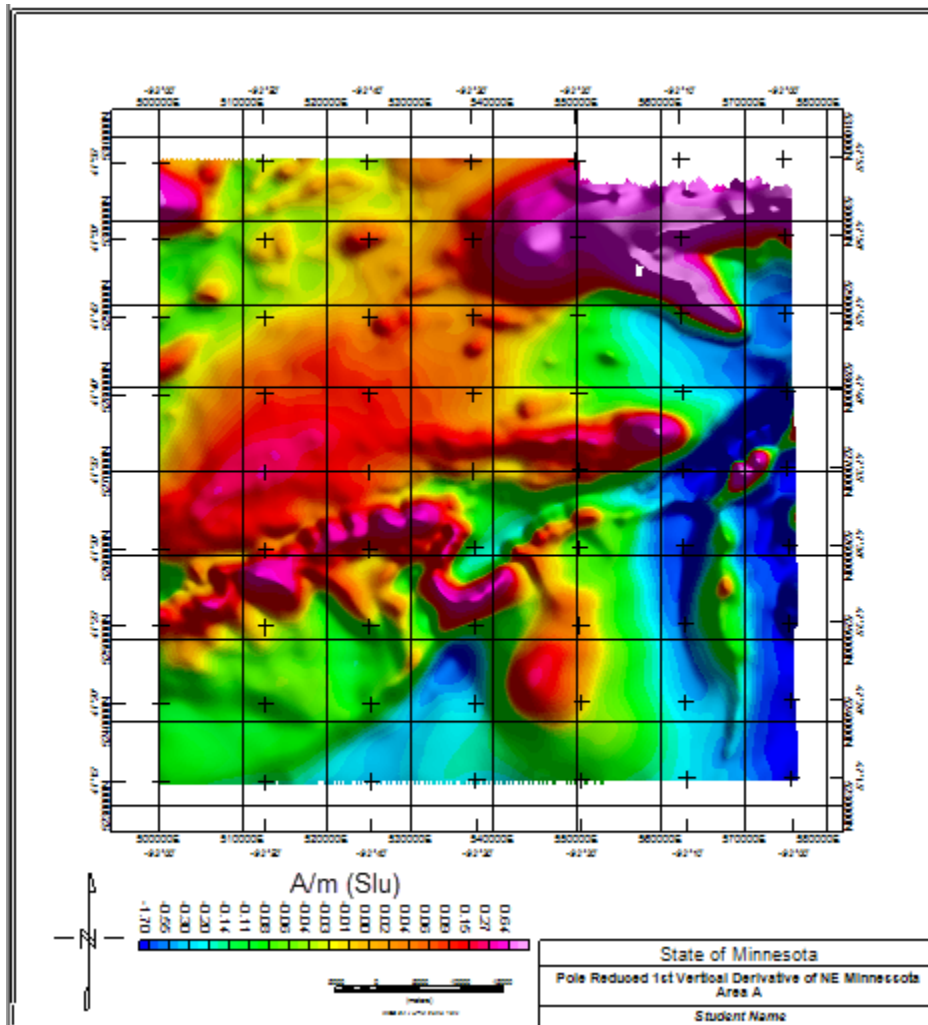


Figure 37: Apparent susceptibility map for area A.

Pseudo-gravity Filter

Figure 38 illustrates the relevant templates and output from filtering the magnetic anomaly grid of area A for pseudo-gravity effects in milligals, assuming geomagnetic field strength [intensity], inclination, and declination values determined from the appropriate DGRF, and magnetization of 0.5 gauss [= 0.5×10^3 A/m in SI] and density contrast of 1.0 g/cm³ [= 1.0×10^3 kg/m³ in SI].

Proceed to calculate the Pseudo-gravity anomaly grid and display it on the current map.

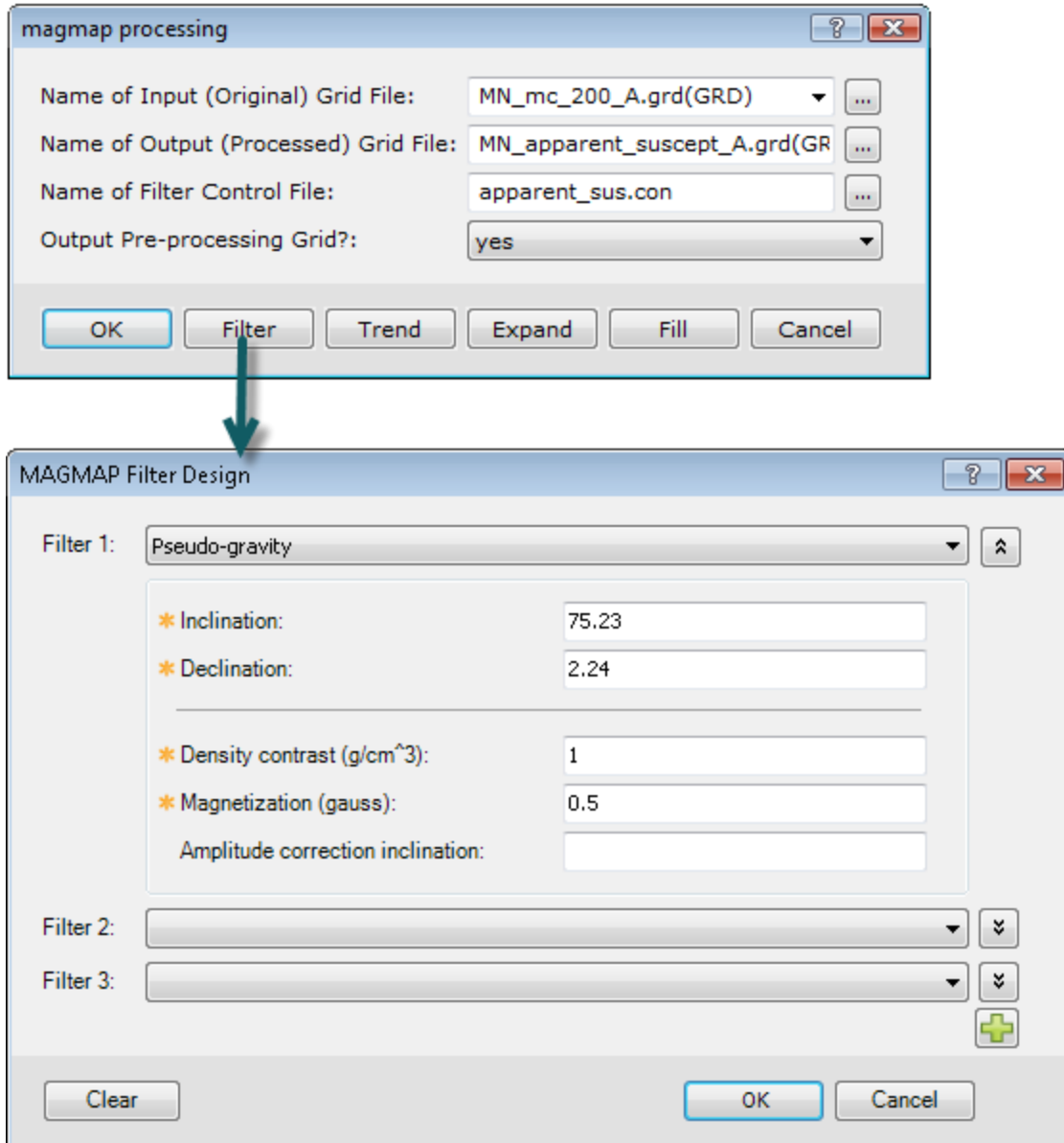


Figure 38: Pseudo-gravity calculation templates.

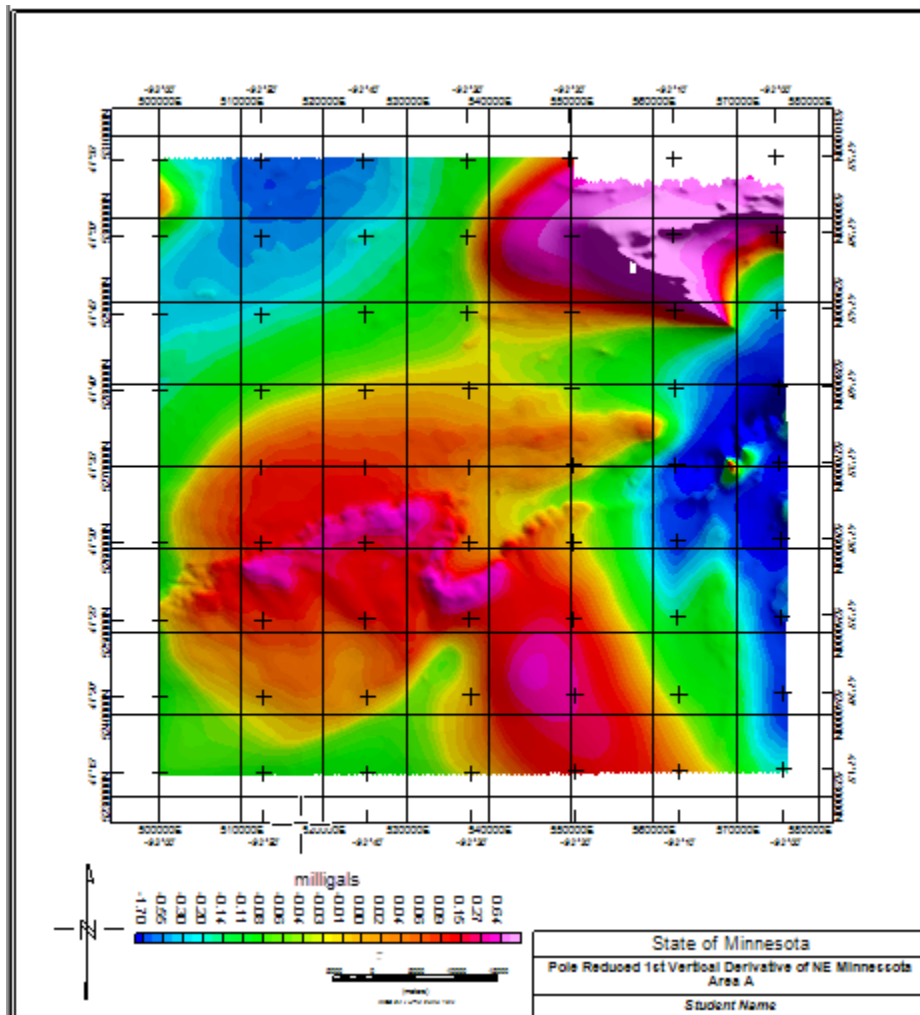


Figure 39: Pseudo-gravity map calculated from the magnetic anomaly.

Profile Preparation

Profiles taken from the grid file or along observed traverses [e.g., flight lines, ship tracks, etc.] facilitate elegant 2D modeling and data analysis procedures that are most applicable where the profile bisects an anomaly with an across-track dimension that is greater than four times the spacing of the profile values [see Hinze et al. (2013), section 13.4].

Profiles from the Grid File

From the project explorer, select the pole reduced anomaly grid file and extract a profile in a desired direction. To do so in your workspace:

1. Create a new database and name it *MN_rtp_profile_A.gdb*.
2. From the **Grid and Image** menu, click **Utilities**, then click **Grid Profile**.
3. Select **Grid 1** as *MN_rtp_A.grd* from which to extract the line.
4. Name the extracted line *MN_rtp_profile_A* [Figure 40].
5. Select *Digitize from map* to define the profile.

6. Click **OK**

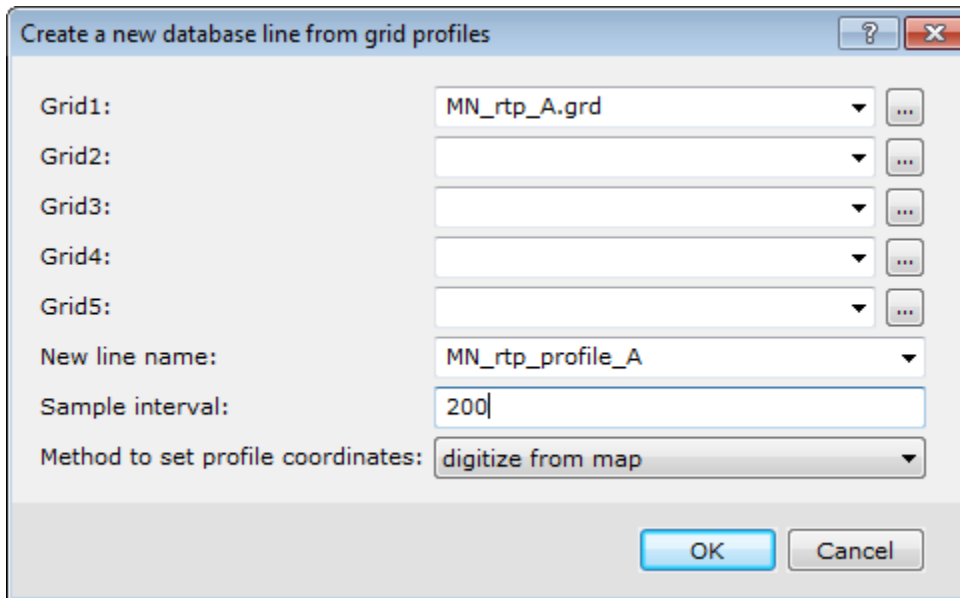


Figure 40: Grid profile dialogue box.

The map is now at the forefront for you to define the profile path by:

1. Left-clicking the first point on the grid map to mark one end of the profile, and left-clicking the second point to mark the other end of the profile
2. Right-click and select **Done**.

Display the Profile and the Path on the Map

1. From the **Map Tools** menu, click **Line path...** and select the appropriate entries. It is recommended to draw the path in, but the line label is not necessary.
2. From the **Map Tools** menu, click **Profile...** and select appropriate entries for the resulting dialogue box.
3. Select *G_MN_rtp_A* file as the **Profile channel**.
4. Select 25 units/mm for the **profile scale**.
5. Select *white* as the **profile colour**.
6. Click **OK** to display the profile on the currently open map, superimposed on the colour anomaly grid [Figure 41].

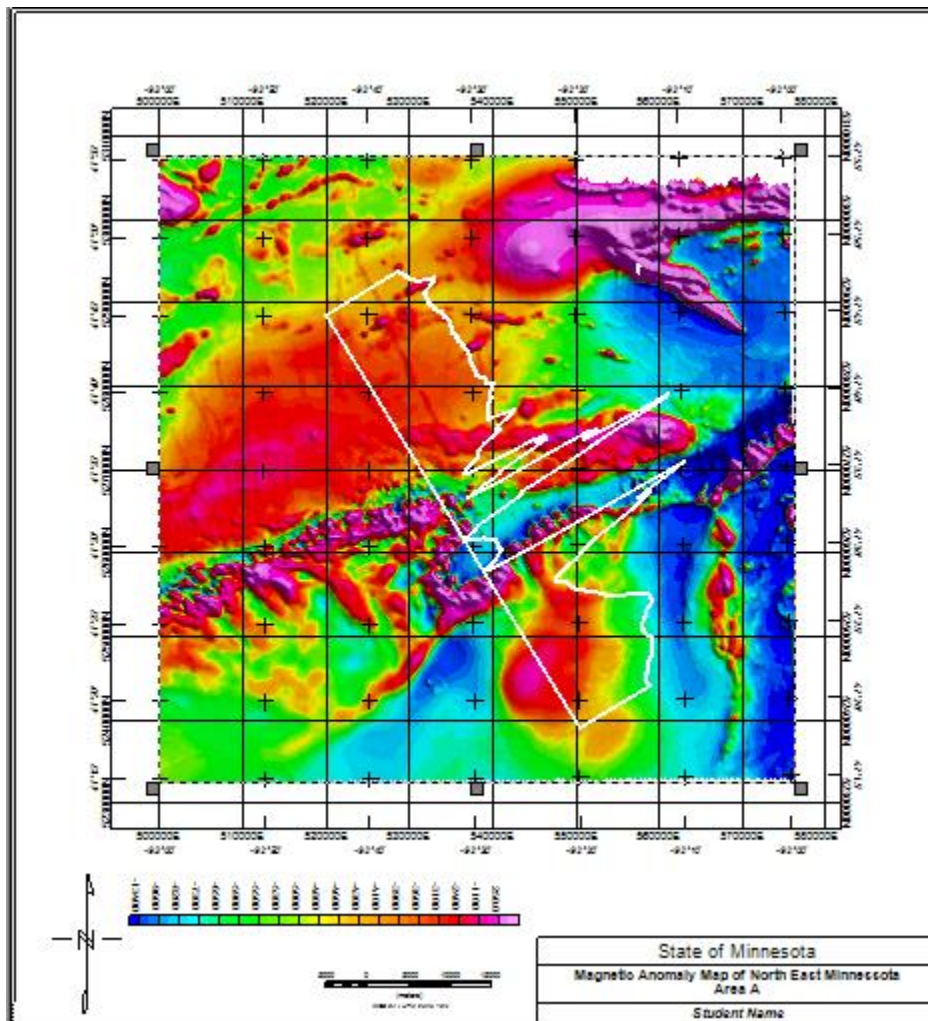


Figure 41: Profile of the RTP observations in nanoteslas superimposed on the map.

Display the Profile in Isolation

To display the profile in isolation in a window with axes aligned with the margins of the page,

1. Click on the database *MN_rtp_profile_A.gdb*. This database only has channels for the (X, Y, amplitude)-components of the data,
2. Right-click on the header of the amplitude column *G_MN_rtp_A*.
3. Click **Show Profile** to obtain a profile view such as illustrated in *Figure 42*.

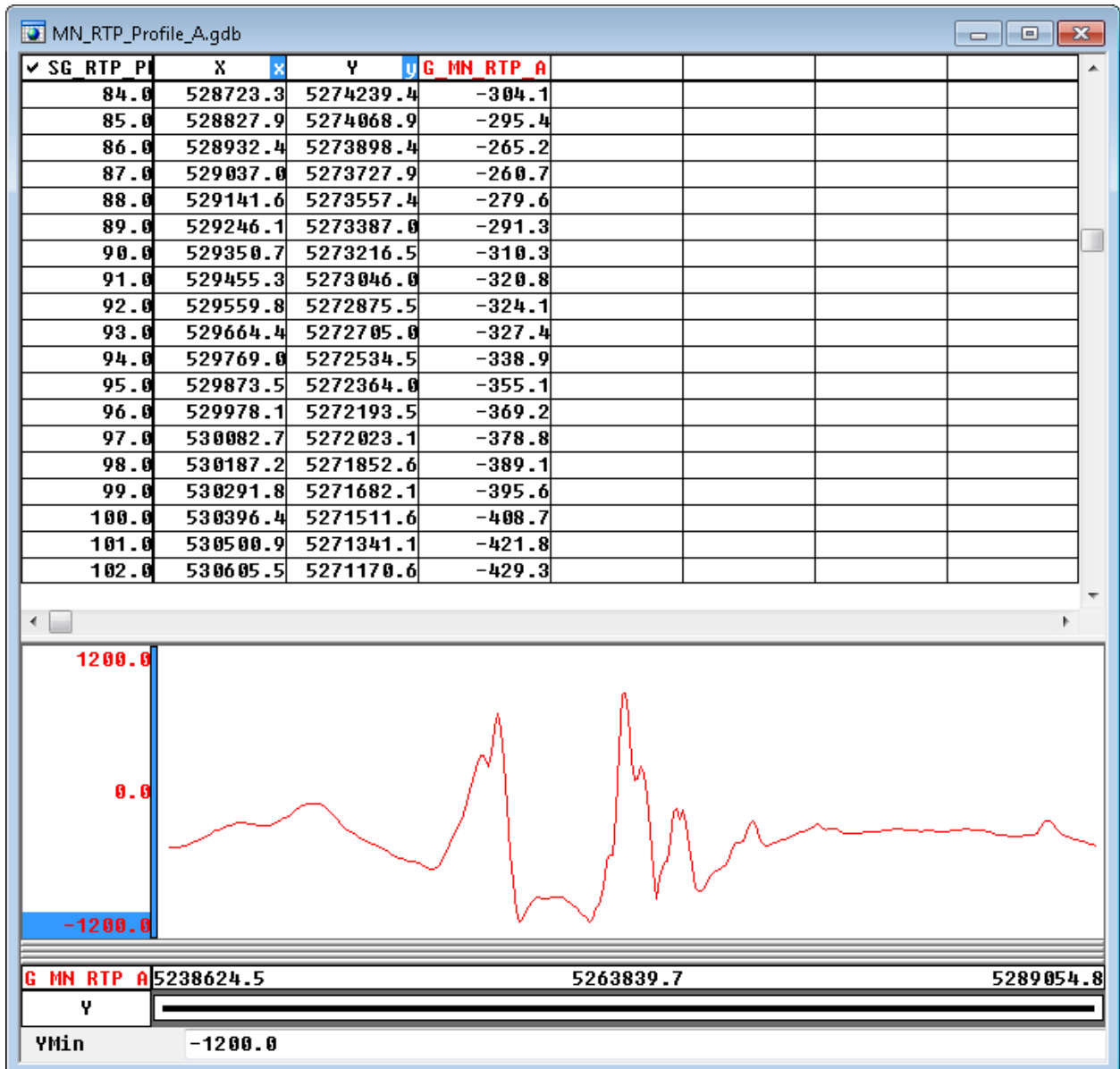


Figure 42: RTP Profile in nanoteslas displayed in the database profile window.

Next create a map file from the profile by:

1. Right-clicking on the profile and click **Plot Profile Figure**.
2. Title the figure *MN_RTP_Profile_A* [Figure 43]
3. Click **OK** to obtain the profile such as illustrated in Figure 44.

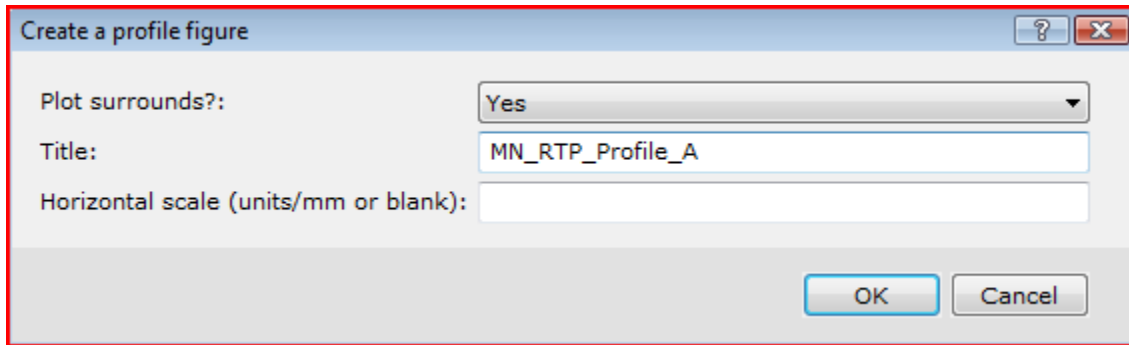


Figure 43: Profile plot template.

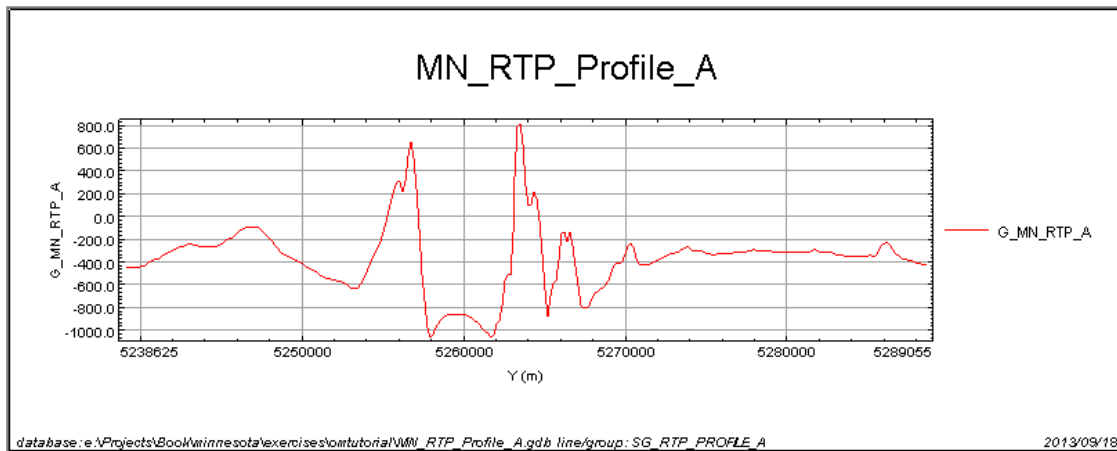


Figure 44: Profile plot of the RTP anomaly in nanoteslas along the digitized oblique line.

Profiles from Survey Traverses

In this section you will merge lines from 2 different surveys that align along one continuous line. *Figure 45* outlines the locations of the Hibbing and Moose Lake surveys. For the sake of conciseness only 2 lines, Lines 110 and 125, of each survey have been provided for this exercise.

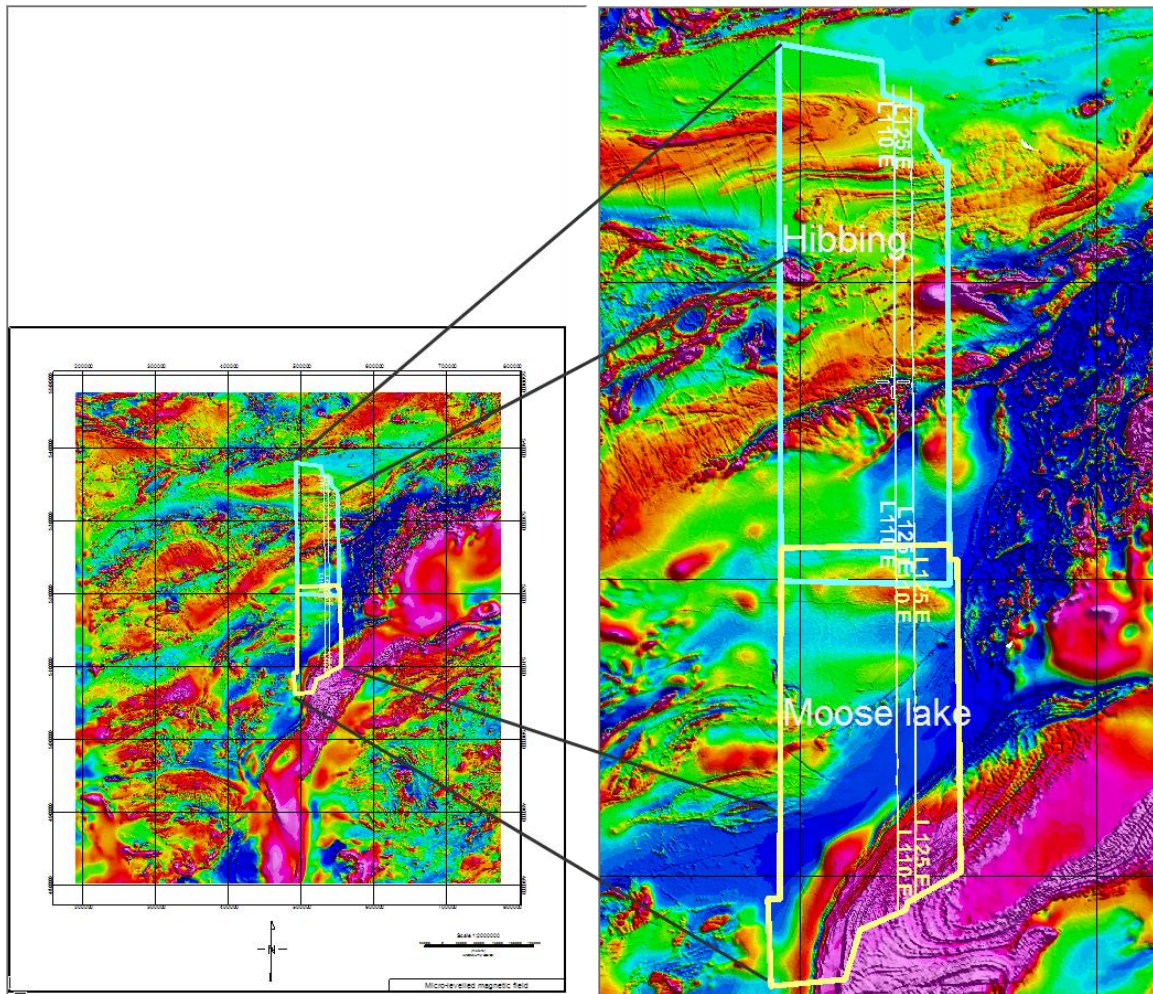


Figure 45: Location of the two database lines to be merged.

Merge the 2 databases together

1. On the **Database Tools** menu, click **Database Utilities** and then click **Merge Databases**.
2. Select *Hibbing2.gdb* to merge it with *Mooselake2.gdb*. Both files have similarly named lines that align. Make sure to choose Append so that lines do not get overwritten [Figure 46].

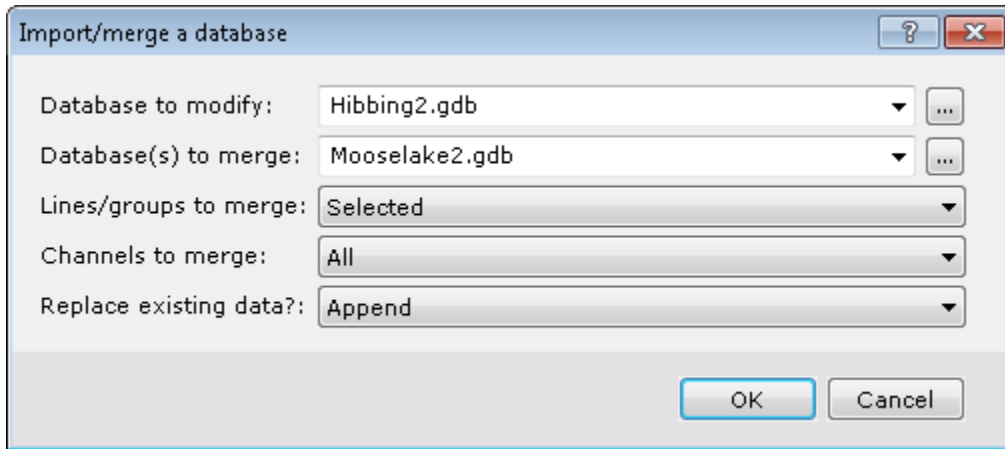


Figure 46: Merge Hibbing2 with Mooselake2.

Although the lines have been merged, the points along the lines are not in the proper order. To order along the Y-axis, you have to sort the data:

1. On the **Database Tools** menu, click **Channel Tools**, then click **Sort all by 2 channels**.
2. Sort first by *UTMN_N83* and then by *UTME_N83*, both in the ascending order
3. To show the *ResidMag* profile in the database window, right-click on the *ResidMag* channel and select **Show profile**.

Sometimes at the join between the 2 lines, the data are not properly leveled and you may need to keep only one of the 2 overlapping segments. Since the map and the database are linked in the *Oasis montaj* workspace, you can move with the cursor down line in the database to observe if there are any discrepancies at the join. The Minnesota data however are well leveled and you do not need to take such corrective measures. On *Figure 47*, the X-axis is plotted in red and the Y-axis in green. No discrepancy can be observed at the join.

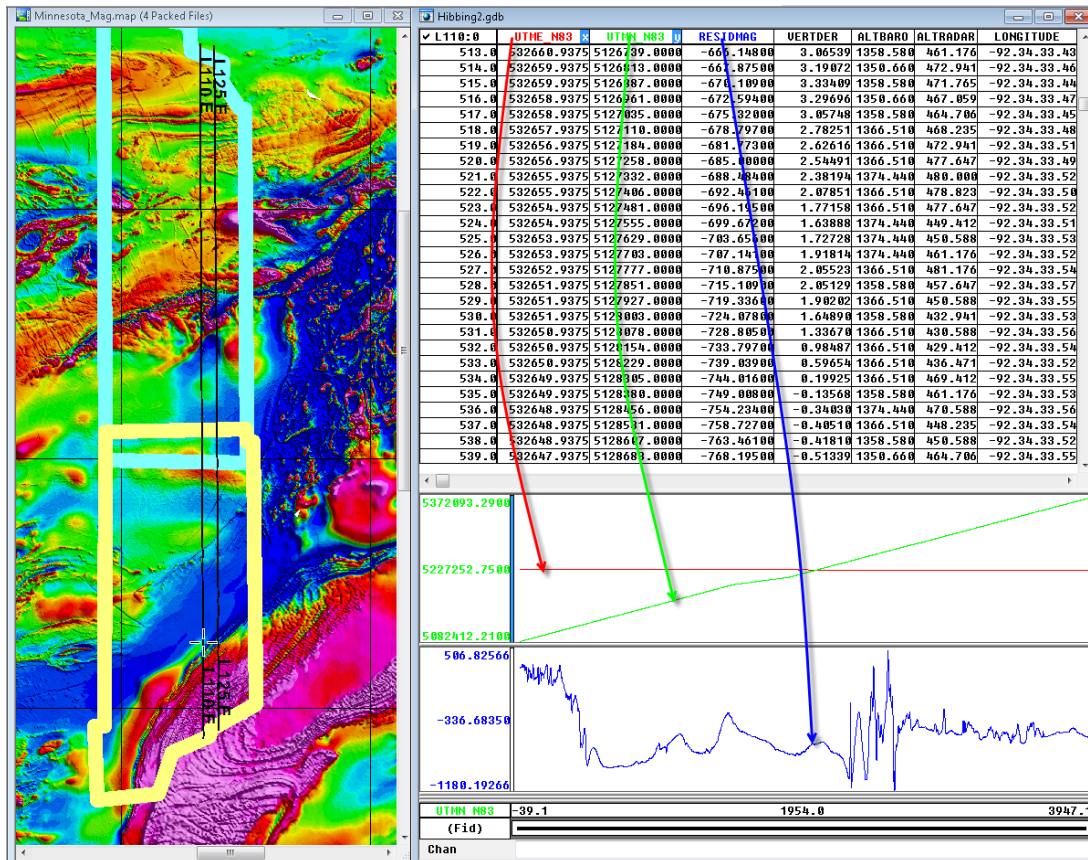


Figure 47: Left: Zoomed map of Minnesota showing the 2 merged lines. The outlines of the 2 surveys have also been plotted as an aid for inspecting the overlap area. Right: For closer inspection the X, Y coordinates have been plotted, along with the ResidMag anomaly profile.

Profile Depth-to-Basement Methods - Pdepth

This section describes how to use the Depth-to-Basement (Pdepth) extension of *Oasis montaj* to determine the position (distance along the profile and depth), dip (orientation) and intensity (susceptibility) of magnetic source bodies for a magnetic profile. With large, distinct density contrasts, the extension can also be used on gravity or gravity gradient profiles to determine the position of gravity source bodies. The Pdepth-techniques include Werner Deconvolution, Analytic Signal and Extended Euler Deconvolution.

Each Pdepth function uses a different accepted technique for determining the depth to the source. Each method has advantages in particular geologic situations. Applying multiple methods to the same anomaly profile greatly improves the reliability of results. Solutions are saved in a new Geosoft GDB (database), enabling you to immediately view the results in profile, edit the solutions, and plot the solutions to 2D and 3D maps. Additional functions also enable you to cluster solutions, export solutions to GM-SYS models, and generate starting GM-SYS models from data profiles.

Hinze et al. (2013) provide further background information on these depth techniques for gravity [p. 191-196] and magnetic [p. 364 – 387] anomaly interpretation.

Using Pdepth

The Pdepth methods operate on all selected lines in the current database. Simply select one of the methods to use. Adjust the method-specific parameters to control the number of solutions generated by the calculations. Note that Pdepth methods recreate the output database each time a method is run, so previous solutions may be overwritten.

To use Pdepth for generating depth-to-basement estimates:

1. From the **GX** menu, click **Load Menu** to display the Load Menu dialog box
2. Select the *pdepth.omn* file, and click **Open**. The Pdepth menu will be added to the *Oasis montaj* menu bar.
3. Make sure to set the database you want to analyze as the current (selected) database.
4. From the **PDepth** menu, select the desired method [i.e., Werner, Analytic Signal, or Extended Euler]. Further information about each of these methods and the related solutions is described below.
5. Fill in the necessary fields to generate the solution, and
6. Click **OK**.

Data Requirements for the Pdepth methods

Each method requires X, Y, elevation, topography and anomaly channels for the input profiles. Topography may be all dummies. The difference between elevation and topography channels is subtracted from the solution depths to generate the channel containing the depth of the solutions relative to sea level, Depth_sl. All channels containing distance units are assumed to use the same units (m, km,..).

All methods require minimum and maximum depths, in the same distance units, that define the solution space. Solutions shallower than the minimum depth or deeper than the maximum depth will be discarded.

Depth to Basement methods are designed primarily for use with total-field or RTP magnetic anomaly data. For each method, you must set the magnetic field parameters to those appropriate to the magnetic survey. However, mathematically the magnetic response is equivalent to the derivative of the gravity response, so it is possible to use the Pdepth methods on gravity profiles by using either the horizontal or vertical derivative of gravity as the input anomaly profile, rather than total-field magnetic data. When using the vertical derivative of gravity, set the Inclination to 90 degrees and the Declination to 0. For the horizontal derivative, set the Inclination to 0, and the Declination to the profile azimuth. Setting the Field Strength to 10 seems to give the best conversion of susceptibilities to densities. However, remember that the susceptibilities calculated for dike solutions are really effective susceptibilities (i.e., susceptibility * width). Also remember that the contact solutions are calculated from the 2nd derivative of the gravity profile. Unless the original gravity profile is

especially clean, the 2nd derivative will tend to be noisy, so the density contrasts calculated are often not very accurate.

The depth methods use horizontal and vertical derivatives in the calculations. You may either specify existing derivative channels to use, or have one or more derivatives calculated from the input channel. If your input profiles are noisy, you can improve the performance of Depth to Basement methods significantly by low-pass filtering or smoothing the anomaly profiles prior to running the methods. This is especially true in the case of gravity profiles, where the derivatives are really 2nd derivatives. The calculated susceptibilities and densities will be less accurate with noisy data. All of the methods assume that the anomaly profile is perpendicular to the geologic structure generating the field. Set the Relative Strike parameter to reflect the clockwise difference between the profile azimuth and the geologic strike.

Generating Werner Solutions

Each Werner Deconvolution calculation operates on a segment of the anomaly profile referred to as a window, and may produce a single solution. Starting at the beginning of the profile using the smallest window size, the window moves along the profile to the end. Then the window size is incremented and the entire profile is processed again.

Werner - generate Werner solutions		Werner Decon Dialog Options	
X Channel	<input type="text"/>	X Channel	Input x coordinate. (Assumes units are the same for X, Y, Elev, and Topo channels).
Y Channel	<input type="text"/>	Y Channel	Input y coordinate. (Assumes units are the same for X, Y, Elev, and Topo channels).
Elev. Channel	<input type="text"/>	Elev. Channel	Flight elevation (+up) relative to sea level. (Assumes units are the same for X, Y, Elev, and Topo channels).
Mag Channel	<input type="text"/>	Mag. Channel	Magnetic (or gravity) anomaly channel.
Horizontal Derivative	<Calculate>	Horizontal Derivative	Input horizontal derivative channel. The key word "Calculate" forces the Werner to calculate derivative from the Mag Channel values.
Topography	<None>	Topography	Topographic elevation (+up) relative to sea level. (Assumes units are the same for X, Y, Elev, and Topo channels. Can be all dummies).
Min. Depth	1	Minimum Depth	Solutions shallower than minimum depth are discarded. (Relative to flight elevation, + down).
Max. Depth	5000	Maximum Depth	Solutions deeper than maximum depth are discarded. (Relative to flight elevation, + down).
Min. Window Length		Minimum Window Length	Length (in horizontal distance units) of shortest Werner operator window used to detect peaks and calculate depths.
Max. Window Length		Maximum Window Length	Length (in horizontal distance units) of longest Werner operator window used to detect peaks and calculate depths.
Window Expansion Increment		Window Expansion Increment	Increment (in horizontal distance units) used to expand the operator window length for successive passes from "Min" to "Max".
Window Shift Increment		Window Shift Increment	At each operator window size, the window will be advanced along the profiles by this distance (in horizontal distance units) for successive calculations.
Detrend Order	1	Detrend Order	Degree of polynomial used to calculate the regional removed from the data window. The allowable range is 0-2. (Default 1, i.e., linear regional).
Relative Strike	90.0	Relative Strike	Angle between profile direction and anomaly strike in degrees, positive counterclockwise. (Default 90 degrees).
Field Strength	50000.0	Field Strength	Earth's magnetic field strength. Used to calculate susceptibility which will be in same units.
Inclination	60.0	Inclination	Earth's magnetic field inclination in degrees.
Declination	20.0	Declination	Earth's magnetic field declination in degrees.
Residual cut-off	0.0	Residual Cut-Off	Data windows with RMS residual (after regional removed) less than this value are discarded. Larger values generate fewer solutions. (Default 0, i.e., keep all solutions).
X cut-off	20.0	X Cut-Off	Solutions outside this distance (in % of window length) from the center of the window are discarded. Larger values generate more solutions. The allowable range is 5%-100%. (Default 20%).
Output Database Name	<input type="text"/> ...	Output Database Name	If a database with this name exists, Werner replaces existing lines with the new results but maintains the existing format and structure.

Figure 48: Werner Deconvolution depth estimation dialogue box and parameter definitions.

You may elect to have a trend removed from each window as part of the calculation. In the Detrend Order parameter, specify 0-order, 1st-order, or 2nd-order trend removal.

Parameters to control the number of solutions generated by Werner include:

- Min. Window Length to set the minimum lengths of the Werner operator,
- Max. Window Length to set the maximum lengths of the Werner operator,
- Window Expansion Increment to determine the number and size of steps between the minimum and maximum, and
- Window Shift Increment to set the distance the Werner operator is moved along the profile between calculations.

These four parameters are specified in distance units. Smaller values of the Window Expansion Increment and Window Shift Increment generate more calculations and hence more solutions.

Each Werner calculation potentially generates a single solution. Two input parameters determine whether a calculated solution will be saved in the output database: Residual cut-off sets an amplitude threshold for anomalies (in nT units) and allows you to eliminate solutions caused by noise in the input profile. Larger values of Residual cut-off eliminate more solutions. X cut-off sets a horizontal distance threshold (in fiducials units) for solutions relative to the center of the Werner operator. When X cut-off is decreased, more solutions are eliminated. Values of X cut-off greater than 2, combined with small values of Window Shift Increment, generate the spray patterns seen in some examples in the literature. The Werner Deconvolution method will not find many valid solutions at depths shallower than the input data spacing or deeper than the window length.

For additional information on Werner Deconvolution, see Hinze et al. (2013; p.192, and p. 374), and Ku and Sharp (1983).

Generating Analytical Signal (AnaSig) Solutions

When using the Analytic Signal method on gravity profiles use the horizontal derivative of gravity as the input profile rather than total-field magnetics. If the Field Strength is set to 1, Inclination set to 90, and the Declination set to zero the Susc output channel will be the calculated density contrast. Note that the Contact solutions are computed from the 2nd horizontal derivative in the gravity case, so some low-pass filtering is often required.

ANASIG Dialog Box Options	
X Channel	Input x coordinate. (Assumes units are the same for X, Y, Elev, and Topo channels).
Y Channel	Input y coordinate. (Assumes units are the same for X, Y, Elev, and Topo channels).
Elev. Channel	Flight elevation (+up) relative to sea level. (Assumes units are the same for X, Y, Elev, and Topo channels).
Mag. Channel	Magnetic (or gravity) anomaly channel.
Horizontal Derivative	Input horizontal derivative channel. The key word "Calculate" forces the ANASIG to calculate derivative from the Mag Channel values.
Topography	Topographic elevation (+up) relative to sea level. (Assumes units are the same for X, Y, Elev, and Topo channels. Can be all dummies).
Minimum Depth	Solutions shallower than minimum depth are discarded. (Relative to flight elevation, + down).
Maximum Depth	Solutions deeper than maximum depth are discarded. (Relative to flight elevation, + down).
Minimum Window Length	Length (in horizontal distance units) of shortest ANASIG operator window used to detect peaks and calculate depths.
Maximum Window Length	Length (in horizontal distance units) of longest ANASIG operator window used to detect peaks and calculate depths.
Window Expansion Increment	Increment (in horizontal distance units) used to expand the operator window length for successive passes from "Min" to "Max".
Relative Strike	Angle between profile direction and anomaly strike in degrees, positive counterclockwise. (Default 90 degrees).
Field Strength	Earth's magnetic field strength. Used to calculate susceptibility which will be in same units.
Inclination	Earth's magnetic field inclination in degrees.
Declination	Earth's magnetic field declination in degrees.
Output Database Name	If a database with this name exists, ANASIG replaces existing lines with the new results but maintains the existing format and structure.

Figure 49: Analytic Signal depth estimation dialogue box and parameter definitions.

Parameters to control the number of solutions generated by the Analytic Signal (AnaSig) method include:

- Min. Window Length to set the minimum lengths of the analytic signal operator,
- Max. Window Length to set the maximum lengths of the analytic signal operator, and
- Window Expansion Increment to determine the number and size of steps between the minimum and maximum.

These three parameters are specified in distance units. The distance units in the input parameters are always the same as those for the X and Y input channels. For example, if the X, Y channels are in metres, all the distance, depth inputs and outputs will be in metres. Smaller values of Window Expansion Increment generate more calculations and hence more solutions. Each analytic signal calculation may generate a single solution. After a local peak is detected in the anomaly profile, operators that vary from Min. Window Length to Max. Window Length are used to calculate an interpolated location for the peak and a depth.

For additional information on analytic signal depth to source estimation, please refer to Hinze et al. (2013; p. 382), and Nabighian (1972, 1974).

Generating Extended Euler (EsxEuler) Solutions

The Extended Euler algorithm used in this method was provided by GETECH based on Mushayandebvu et al. (2001). This approach calculates solutions using both the conventional Euler equation (Reid et al., 1990) and the rotational constraint equation from extended Euler. Solving both equations jointly (extended Euler) gives distance, depth, dip, and susceptibility, assuming there is no remnant magnetization. Using

conventional Euler Deconvolution gives a second estimate for distance and depth. If the relative difference in depth for the two estimates is less than the maximum percentage error given by the user, the solution is retained; otherwise it is rejected.

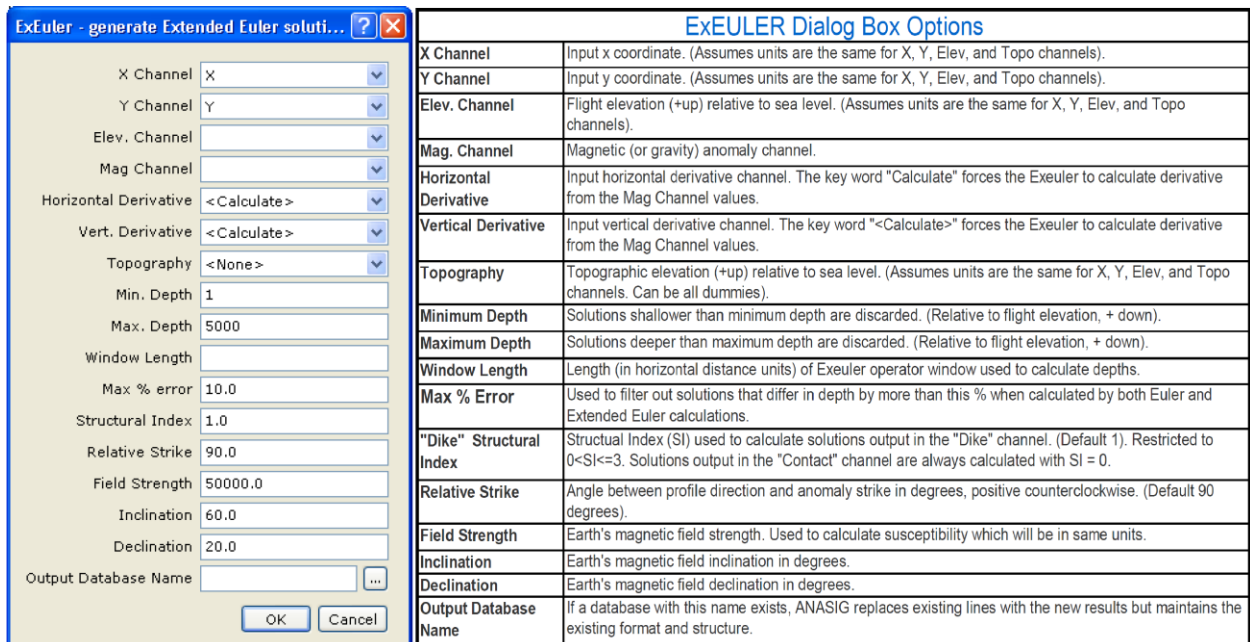


Figure 50: Extended Euler Deconvolution depth estimation dialogue box and parameter definitions.

Parameters to control the number of solutions generated by the extended Euler [ExEuler] operator include:

- Min. Depth to set the minimum depth cut-off,
- Max. Depth to set the maximum depth cut-off,
- Window Length to set the length of the ExEuler operator, which is moved across the profile and is used for each calculation, and
- Max % error used to filter out solutions that differ in depth by more than this stated percentage when calculated by both Euler and Extended Euler calculations.
- The minimum and maximum depths, as well as the window length parameter are specified in distance units. The distance units in the input parameters are always the same as those for the X and Y input channels. For example, if the X and Y channels are in metres, all the distance, depth inputs and outputs will be in metres.
- The Extended Euler method (ExEuler) will not find many valid solutions at depths shallower than the input data spacing or deeper than the window length. ExEuler always makes two passes through the data. The first pass always uses a Structural Index (SI) of zero to calculate contact solutions. The second pass uses the SI given by the user in the dialog entry for Dike Structural Index. The results of the second pass are always flagged as dike solutions regardless of the SI used.

For additional information on Euler and Extended Euler Deconvolution for depth to source estimation, please refer to Hinze et al. (2013; p. 191, and p. 364), Thompson (1982), Reid et al. (1990), and Mushayandebvu et al. (2001).

Displaying Depth Results in *Oasis montaj*

The solutions are written to the separate Output Database specified by the user. Solutions are sorted by distance-along-the-line, referenced to the first point in the input profile.

The channel, Z_Dikes contains the dike solution depths relative to the flight elevation. The channel, Z_Contacts contains the contact solution depths relative to the flight elevation.

All of the solutions are also in a 3rd channel named Z_Both. The channel Depth_sl contains the depths of all solutions relative to sea level, calculated using the input Elev channel if it was non-dummy. Dike0_Cont1 contains a flag identifying the solution as a dike (0) or a contact (1) solution. The sign of the Z-axis is negative down (elevations) for all output channels (Z_Dikes, Z_contacts, Z_Both, Flt_Elev, Topography, and Depth_sl) to facilitate convenient profile plots.

In addition to the calculated solutions, each method samples the input channels Elev, Topography, Mag, Vertical Derivative, and Horizontal Derivative at the location of each solution and copies them into the output database.

As shown below, the Z_Dikes and Z_Contacts channels are plotted as symbols in the bottom panel. The middle panel shows the input magnetic profile and the vertical and horizontal derivatives (either input or calculated). The top panel shows the input flight “elevation” and “topography”.

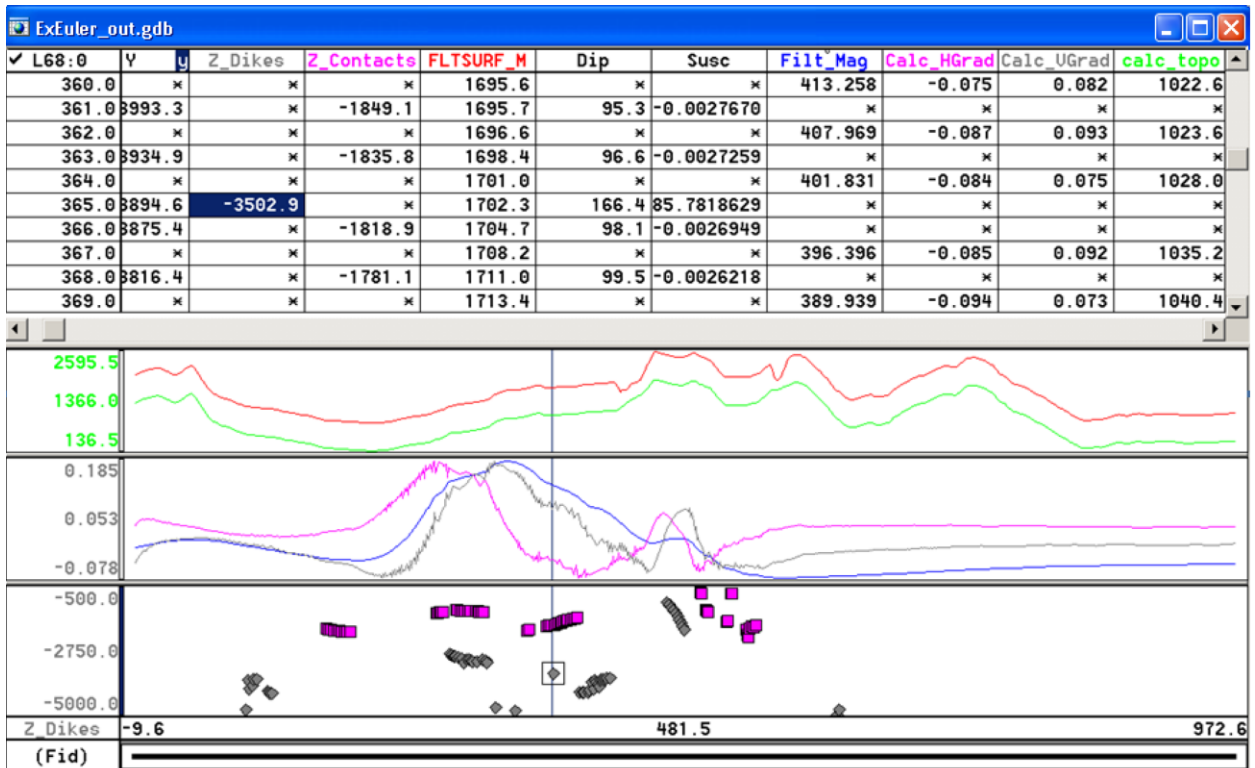


Figure 51: Example of Pdepth database and displayed depth solutions as estimated by the Extended Euler method.

In the Werner method, solutions derived from the total field profile are designated as dike solutions and solutions derived from the horizontal gradient are designated as contact solutions. Dike and contact solutions are flagged in the Dyke0_Cont1 channel by a "0" or "1" respectively. Note that the flag values may conflict with the SI designation in the ExEuler method, but are consistent with the other methods in Pdepth.

To separate dike and contact solutions (in the Depth_sl channel for example), select Simple windowing from the PDepth menu and use 0 - 0 for dike solutions or 1 - 1 for contact solutions. From there, select Build solution channel from the PDepth menu to generate a channel containing just dike solutions or just contact solutions.

3. Gravity Data Processing

This section considers gravity observations that were reduced to simple Bouguer gravity anomalies using a density of $2,670 \text{ kg/m}^3$ and standard procedures (Chandler, 1996; Chandler and Schaap, 1991). Observations were made at intervals ranging generally from 1.6 to 5 km, although the separation between observations may be as large as 10 km where ground access was limited. For the Geosoft-based exercises, the gravity observations are provided in file *MN_Grav_A.csv*.

To better appreciate the distribution of the gravity stations for anomaly analysis, produce a station coverage map for the file *MN_Grav_A.csv*.

Gravity Data Import

To import the Minnesota gravity data provided for the exercise:

1. From the **Database** menu, click **New Database**. Name it *MN_gravity_A*, and save it to the *Minnesota* folder.
2. From the **Database** menu, click **Import** and then click *ASCII* file.
3. Select the *MN_Grav_A.csv* file.
4. Use the Wizard to insure that the channels are properly set as indicated in *Figure 52*.
5. Click **Finish** and save the template as *MN_Grav_A.i3*.
6. Click **Yes** to import data into the current database template.
7. Click **OK** and then click **OK** again to trigger the data import.

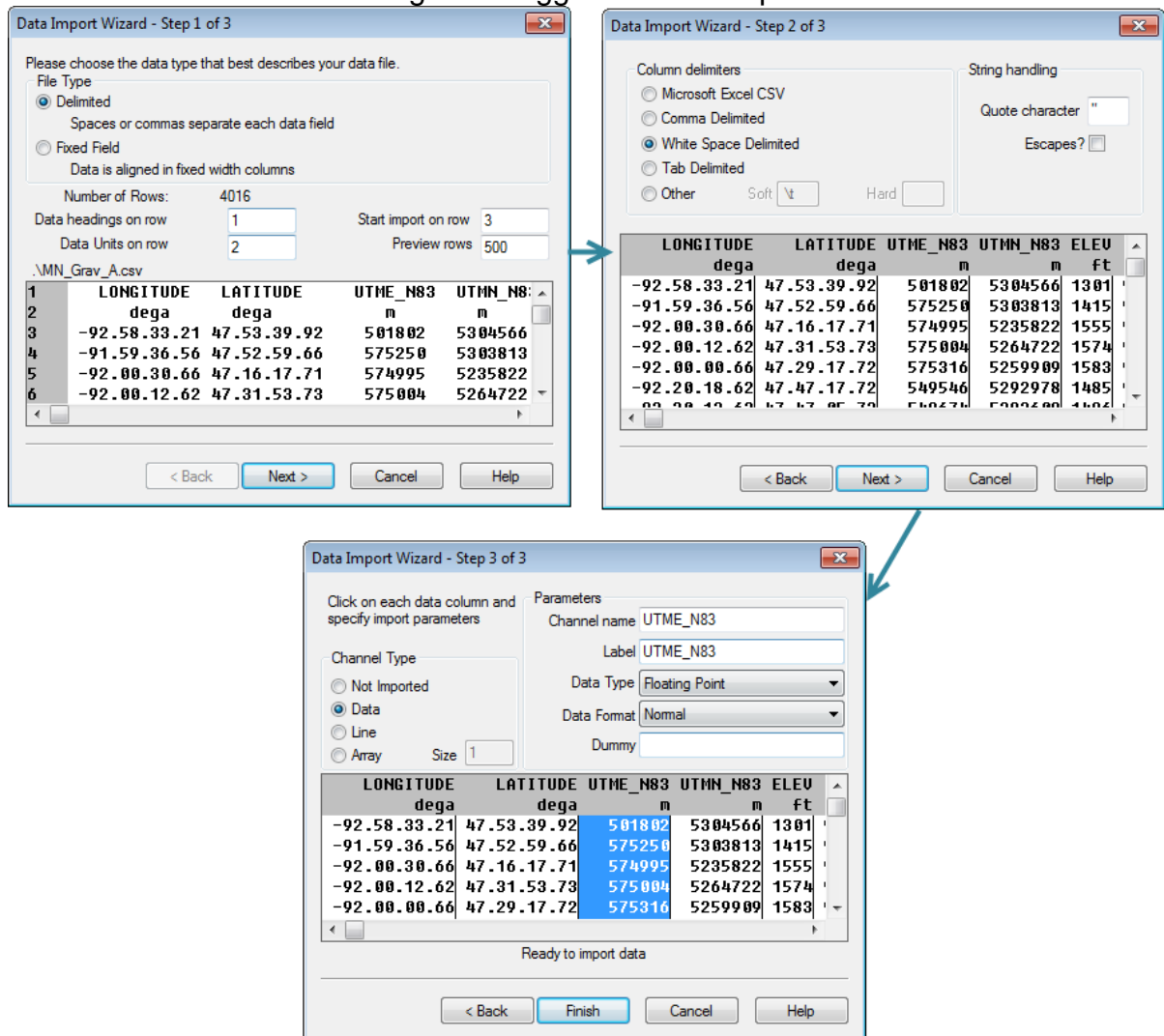


Figure 52: Data import template and settings for importing the gravity station values in file *MN_Grav_A.csv*. The attributes of the channel highlighted in blue, are displayed and can be edited.

Station Location Plots

To plot the station locations, the database channels must be unprotected. To do so, place cursor on the black triangle in the upper left corner of any channel label and

1. Right-click and select **Protect None** to free all of the channels.
2. From the **Coordinates menu**, click **X,Y,Z coordinates...** to set the *UTME_83* and *UTMN_83* as the respective x- and y-channels. Be sure that the new map dimensions are the same as those of the magnetic maps to facilitate spatial comparisons.

To pick a symbol to mark the gravity stations:

1. From the **Map Tools** menu, click **Symbols**, then **Proportional Size**. Obtain and set the template in *Figure 53*.

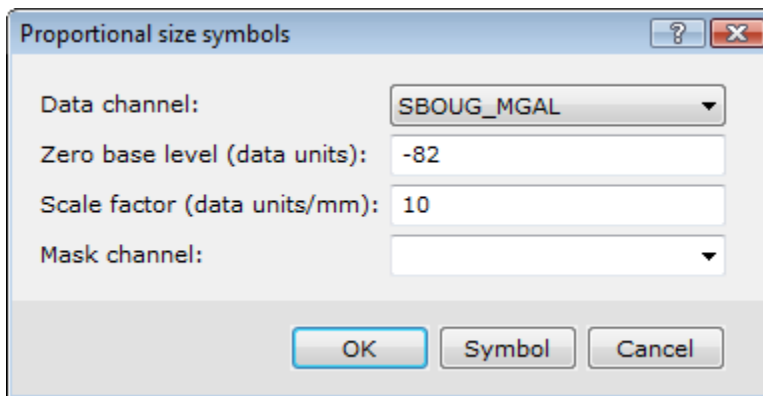


Figure 53: template and settings for marking the gravity station values in file *MN_Grav_A.csv* with proportional sized symbols.

2. Click the **Symbols** button and select a symbol and symbol size as suggested in *Figure 54*.

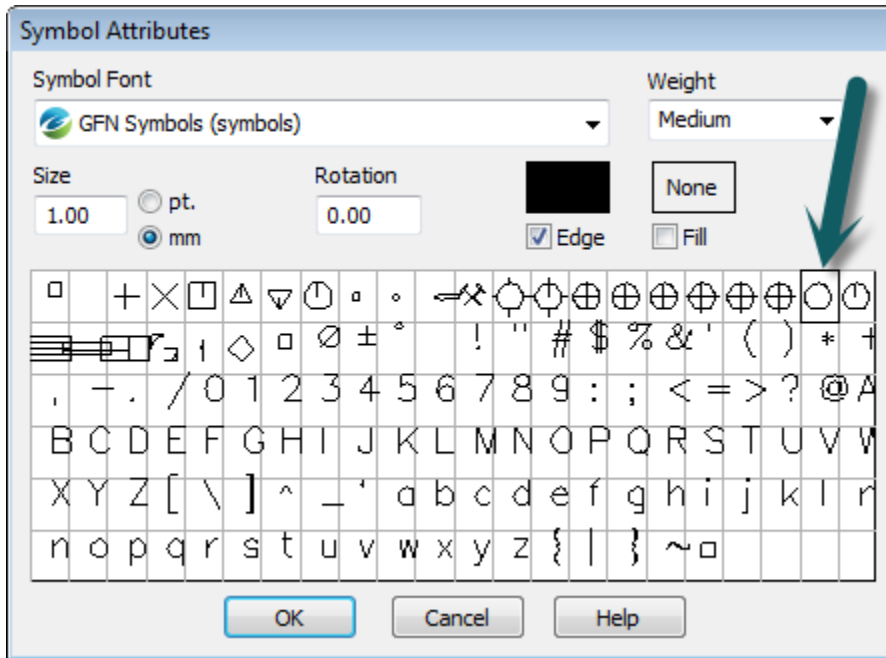


Figure 54: Template and settings for selecting a symbol [e.g., in this case, a circle with diameters proportional to the anomaly values] to mark the gravity station locations of file *MN_Grav_A.csv* as shown in Figure 55.

Gridding

To grid the gravity values from the stations located in *Figure 52* at 800-m intervals by minimum curvature:

1. From the **Grid and Image** menu, click **Gridding**, then click **Minimum Curvature...**
2. Grid the Bouguer gravity anomaly file *MN_Grav_A.csv* at a grid cell size of 800 m, and name the new grid file *MN_gravity_mc_800_A*.
3. Create a .zon file with the magnetic data and name this file *MN_grav.zon*.
4. Add these data to the same base map used for the magnetic data, but use the *MN_Grav.zon* file for the colours.
5. Add a new horizontal colour bar based on the new .zon file and disable the other colour bars by deselecting them in the **View/Group Manager Tool**.
6. Change the title in the title block by double-clicking the words and inserting *Bouguer Gravity of Northern Minnesota* words. *Figure 55 3* shows these minimum curvature gridded gravity anomaly values.

Anomaly Analysis

The gravity anomalies may be processed to help isolate and enhance wavelength, directional, derivative, continuation, pseudomagnetic and other components [see Hinze et al. (2013), sections 6.5 and A.5] using *Oasis montaj* templates comparable to those described above for magnetic anomaly filtering. In addition, gravity profiles

may be taken through the anomalies to focus better on key subsurface source parameters using templates comparable to the magnetic ones described above.

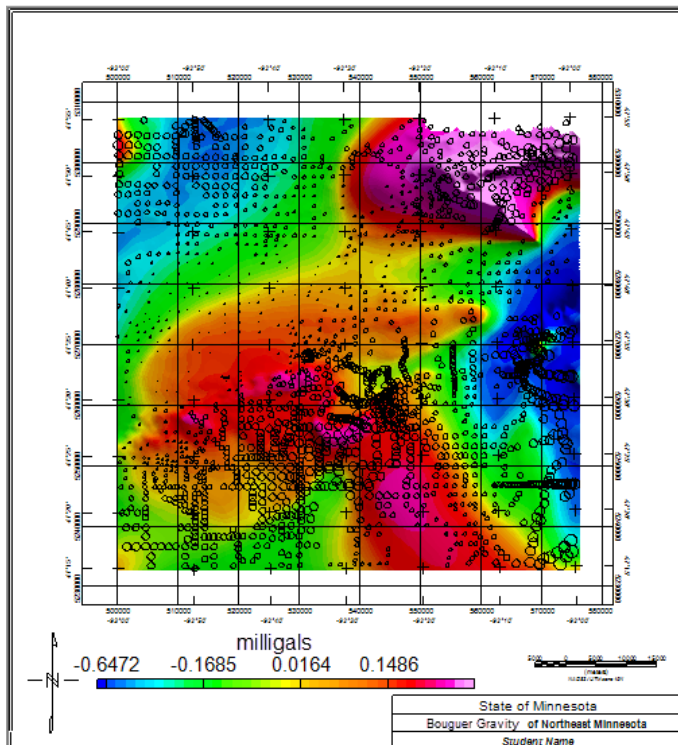
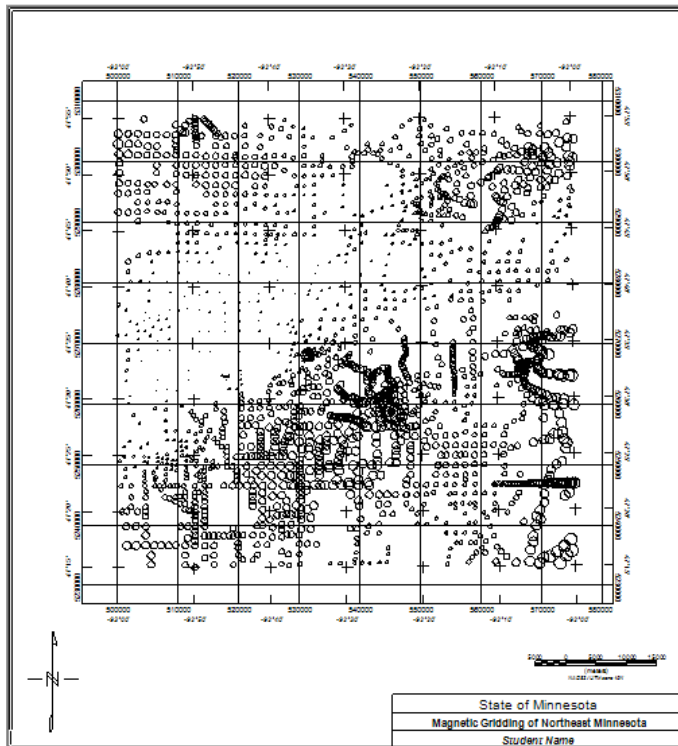


Figure 55: Gravity stations marked with appropriately sized circle-symbols [upper] plotted on the minimum curvature anomaly estimates [lower].

4. Sending Files

Geosoft files may be electronically distributed in their entirety by packing them to include all map construction file elements.

To pack the map:

1. From the **Map** menu, click **Pack Map Files** so that all of the ancillary information transfers along with the map. However, this packing also can create very large file sizes.
2. *Oasis montaj* graphics may also be distributed in standard picture formats [e.g., jpg, tiff, GeoTIFF, png, etc.].
3. On the **Map** menu, click **Export**.
4. Select the desired format from the available option list.

5. Conclusion

Oasis montaj offers an extensive package of data analysis and graphics programs for investigating the gravity and magnetic exploration topics in Hinze et al. (2013). The above sections offer only a cursory introduction to the package, and it is strongly encouraged that you explore aggressively the many high-level capabilities of *Oasis montaj* to better appreciate its power in analyzing and interpreting potential field observations.

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